(NASA-TM-82457) STS-2 INDUCED ENVIRONMENT CONTAMINATION MONITOR (IECM): QUICK-LOOK REPORT (NASA) 76 p HC A05/MF A01 CSCL 06K

N82-18870

Unclas
G3/54 09106

NASA TECHNICAL MEMORANDUM

NASA TM-82457

STS-2 INDUCED ENVIRONMENT CONTAMINATION MONITOR (IECM) – QUICK-LOOK REPORT

Edited by E. R. Miller
Space Sciences Laboratory

January 1982

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (Rev June 1971)

TABLE OF CONTENTS

I. INTRODUCTION

E. R. Miller

As a result of concern for possible contamination from the induced environment of the Space Shuttle which might place limitations on experiment measurements, goals were established for control of particles and gases that would be emitted by the Space Shuttle. The Induced Environment Contamination Monitor (IECM) (Figure I-1) was designed to provide measurements of particles and gases during prelaunch, ascent, on-orbit, descent, and postlanding mission phases in order to determine the actual environment relative to the established goals.

The IECM comprises ten instruments: (1) Humidity Monitor, (2) Dew Point Hygrometer, (3) Air Sampler, (4) Cascade Impactor, (5) Passive Sample Array, (6) Optical Effects Module, (7) Temperature-Controlled Quartz Crystal Microbalance (TQCM), (8) Cryogenic Quartz Crystal Microbalance (CQCM), (9) Camera/Photometer, and (10) Mass Spectrometer. A detailed description of the IECM systems and instruments is provided in Reference 1.

The first operational measurements by the full complement of IECM instruments were performed on the second Space Shuttle flight (STS-2) in November 1981. The IECM data from the flight are being analyzed. This report provides a summary of the preliminary STS-2 measurement results; a more complete analysis will be provided in a final report to be published later. Section II briefly describes the STS-2 IECM mission. Section III discusses the IECM engineering subsystems performance. Sections IV through X present the preliminary measurement results for the ten instruments. Sections XI and XII present a summary of the IECM operation on STS-2 and briefly discuss future plans for the IECM.

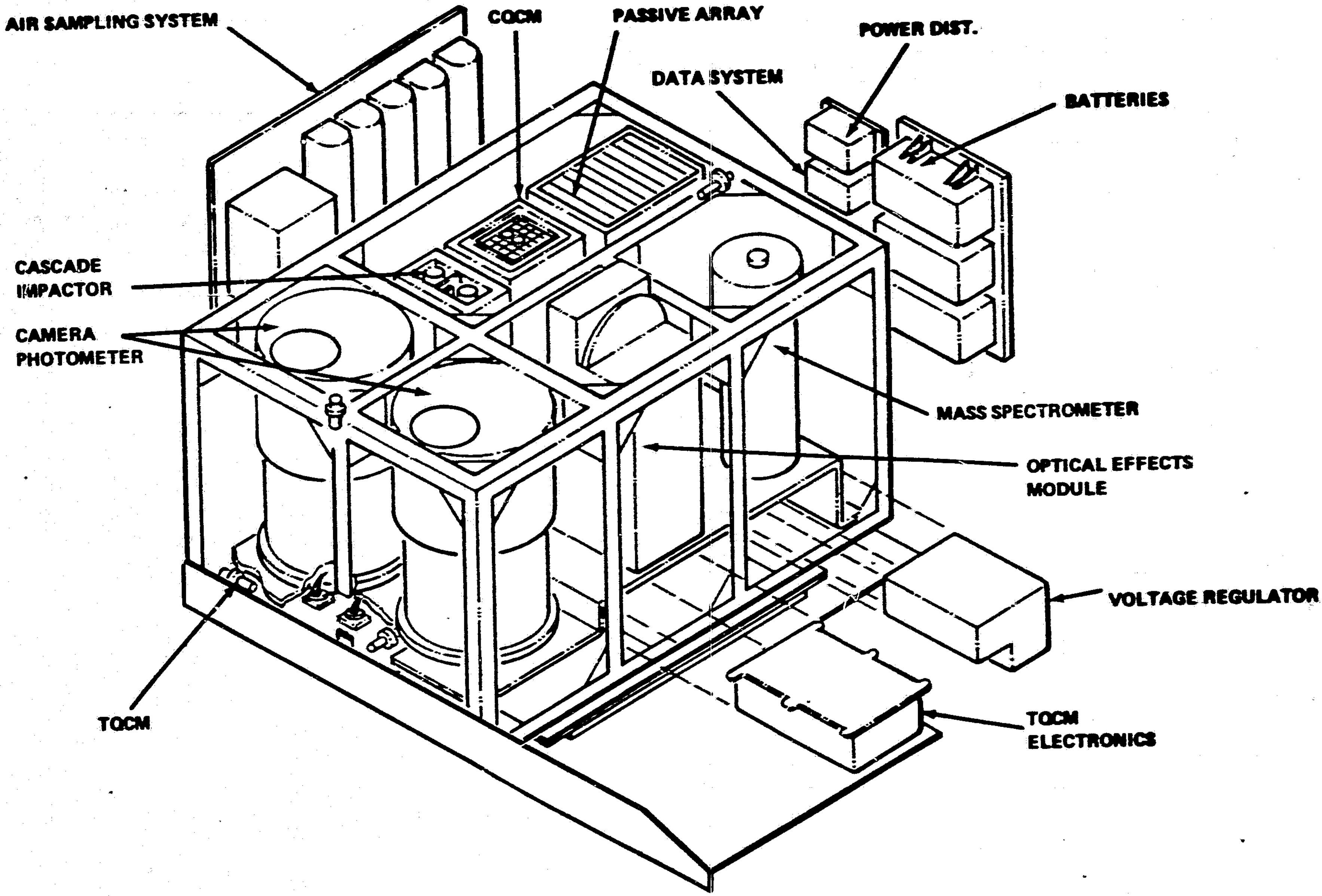


Figure I-1. Induced Environment Contamination Monitor OFT/DFI and Spacelab VFI unit.

II. STS-2 IECM MISSION DESCRIPTION

E. R. Miller

The second flight of the Space Shuttle, containing the OSTA-1 Demonstration Flight Instrumentation (DFI) and the IECM payloads was launched from the Kennedy Space Center (KSC) on November 12, 1981, at 10:10 a.m. (GMT 316:14:10). The flight duration was approximately 54 hr, 16 min. The orbit inclination angle was 38 degrees, and the initial altitude was 223 km. The Orbiter Maneuvering System (OMS) engines 3A, 3B, and 4 were fired at 7:35 (hr:min), 7:47, and 8:35 Mission Elapsed Time (MET), which boosted the vehicle to a near circular orbit of 263 km above the equator. This altitude was essentially maintained until deorbit burn at approximately 53 hr, 15 min MET.

The IECM was mounted on the Release Engage Mechanism (REM) on top of the DFI pallet on July 15, 1981, at X_0 = 1179, Y_0 = 0, Z_0 = 473.3 (top center of IECM). After the IECM/STS-2 interface functional tests were completed, an 11-hr Orbiter Processing Facility (OPF) ground contamination data take was accomplished. The hold at T - 31 s and eventual mission scrub on November 4, 1981, caused the IECM to operate for approximately 10 hr on its batteries at a 3.2 A rate. At T - 4.5 min on launch day, a command through the Multiplexer/Demultiplexer (MDM) turned on the Data Acquisition and Control System (DACS), Power Distributor, and the instruments to be operated during ascent. At T - 0 umbilical disconnect, the IECM ascent data collection began and continued until the on-orbit mode command was sent at 37 min MET. The IECM remained in the on-orbit mode until the descent mode command was sent. The IECM Mass Spectrometer was turned on by an on-board switch at 3 hr, 25 min MET. At 34 hr and 00 min MET, the IECM was powered down for 2 hr and 42 min. Power was restored and IECM operation resumed at 36 hr and 42 min. The Mass Spectrometer was turned off at approximately 49 hr, 25 min MET. The IECM descent mode was initiated at 53 hr, 45 min. Touchdown occurred at Edwards AFB, California, at 54 hr, 15 min MET. The IECM continued to operate in the descent/postlanding mode until power was terminated at 55 hr MET. The STS-2 as-flown timeline is given in Table II-1. Table II-2 gives the as-flown attitude timeline.

Figure II-1 shows the Orbiter body coordinate system and azimuth and co-elevation coordinates associated with the velocity vector, v, the direction of flight. Figure II-2 gives the -Z axis co-elevation angle with respect to the velocity vector, v, calculated from the STS-2 as-flown attitude timeline (Table II-2). Figures II-3 through II-7 provide an expanded scale of Figure II-2.

In addition to the IECM and the DFI hardware, weighing 4556 kg, the STS-2 payload consisted of OSTA-1, five experiments mounted on an engineering model Spacelab pallet weighing 2542 kg. The pallet was located at X_0 = 922. One of the experiments, the Shuttle Imaging Radar-A (SIR-A), contained an antenna 9.35 m long by 1.16 m wide constructed of epoxy-fiberglass honeycomb.

TABLE II-1. STS-2 AS-FLOWN TIMELINE

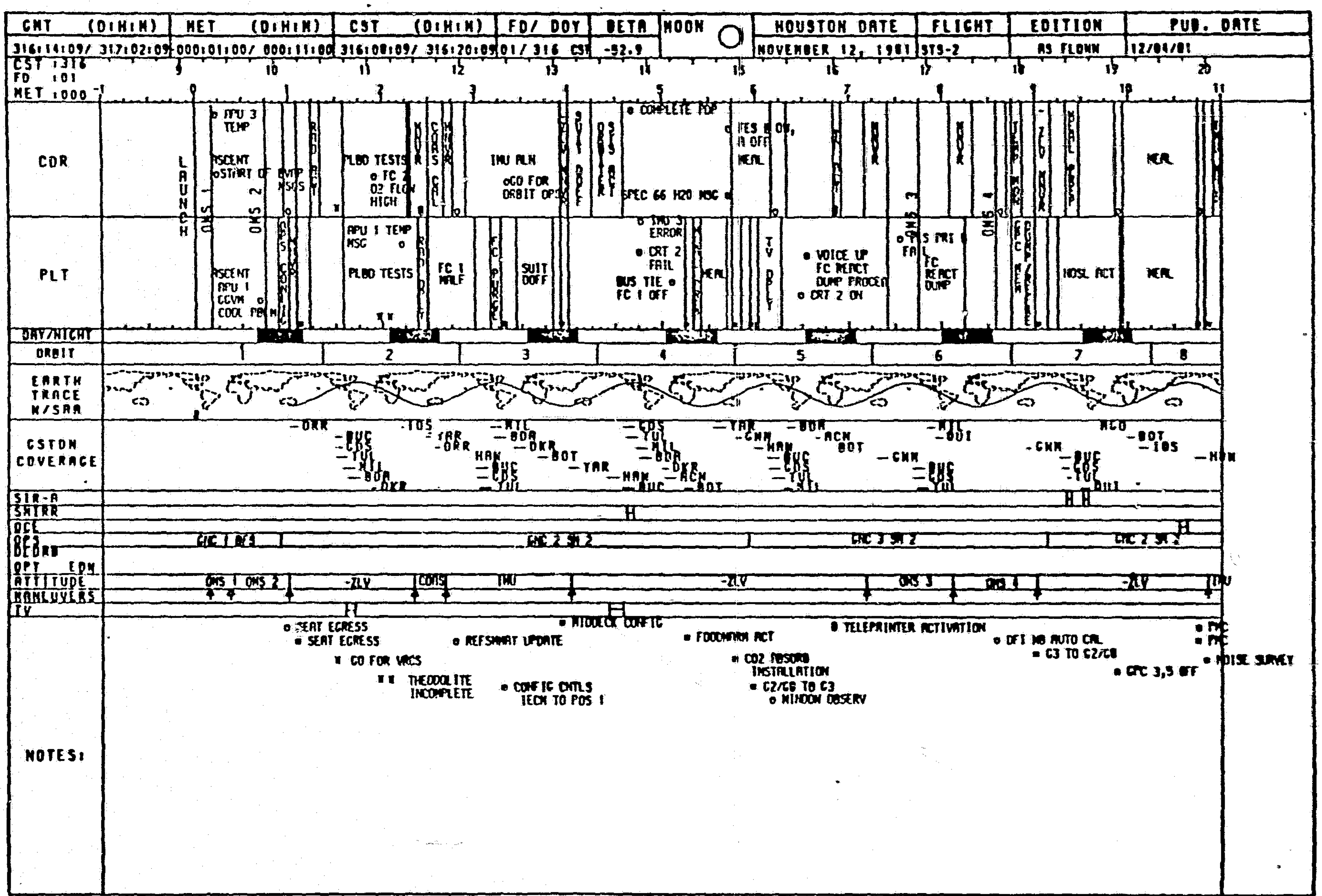
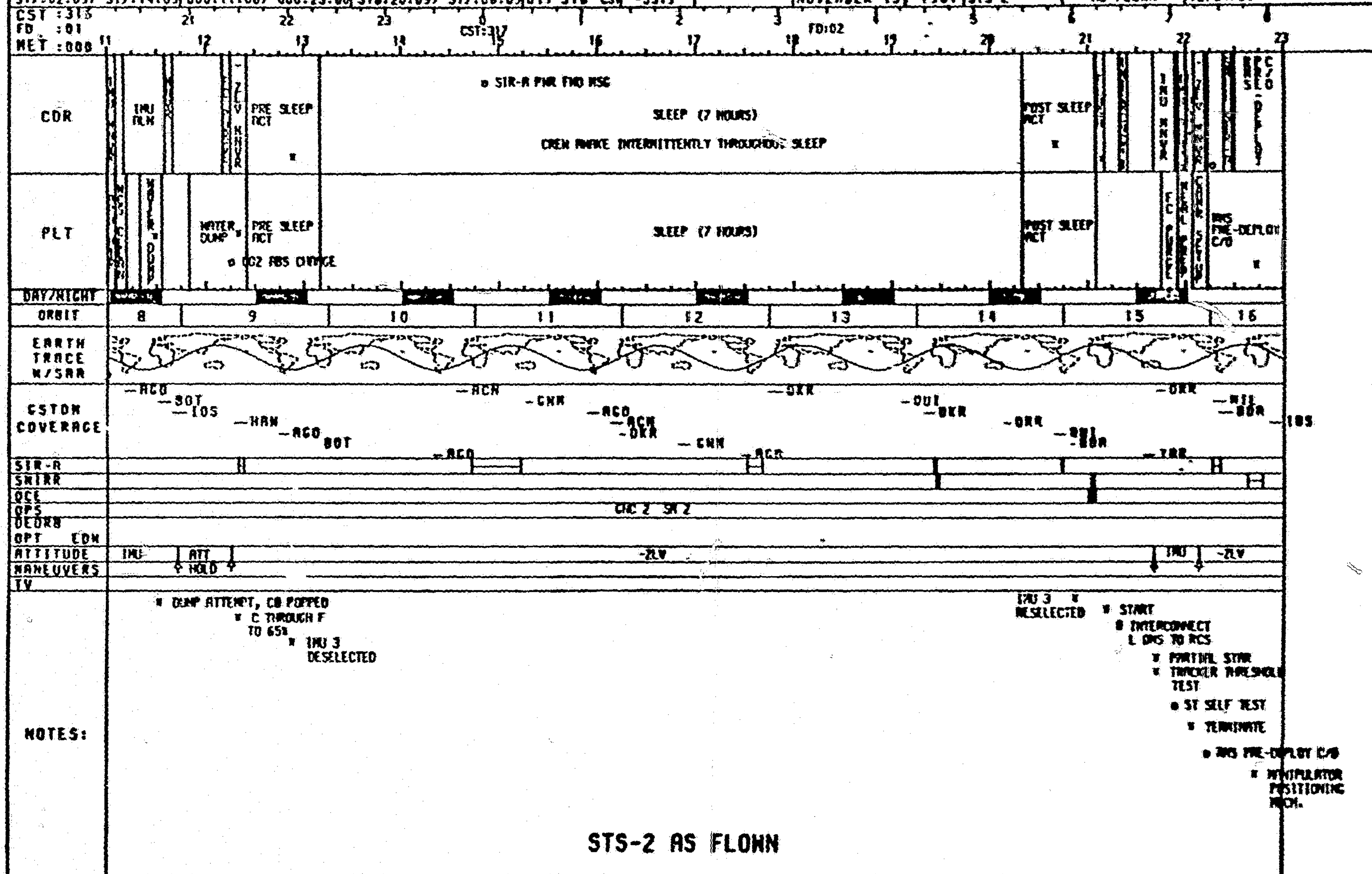


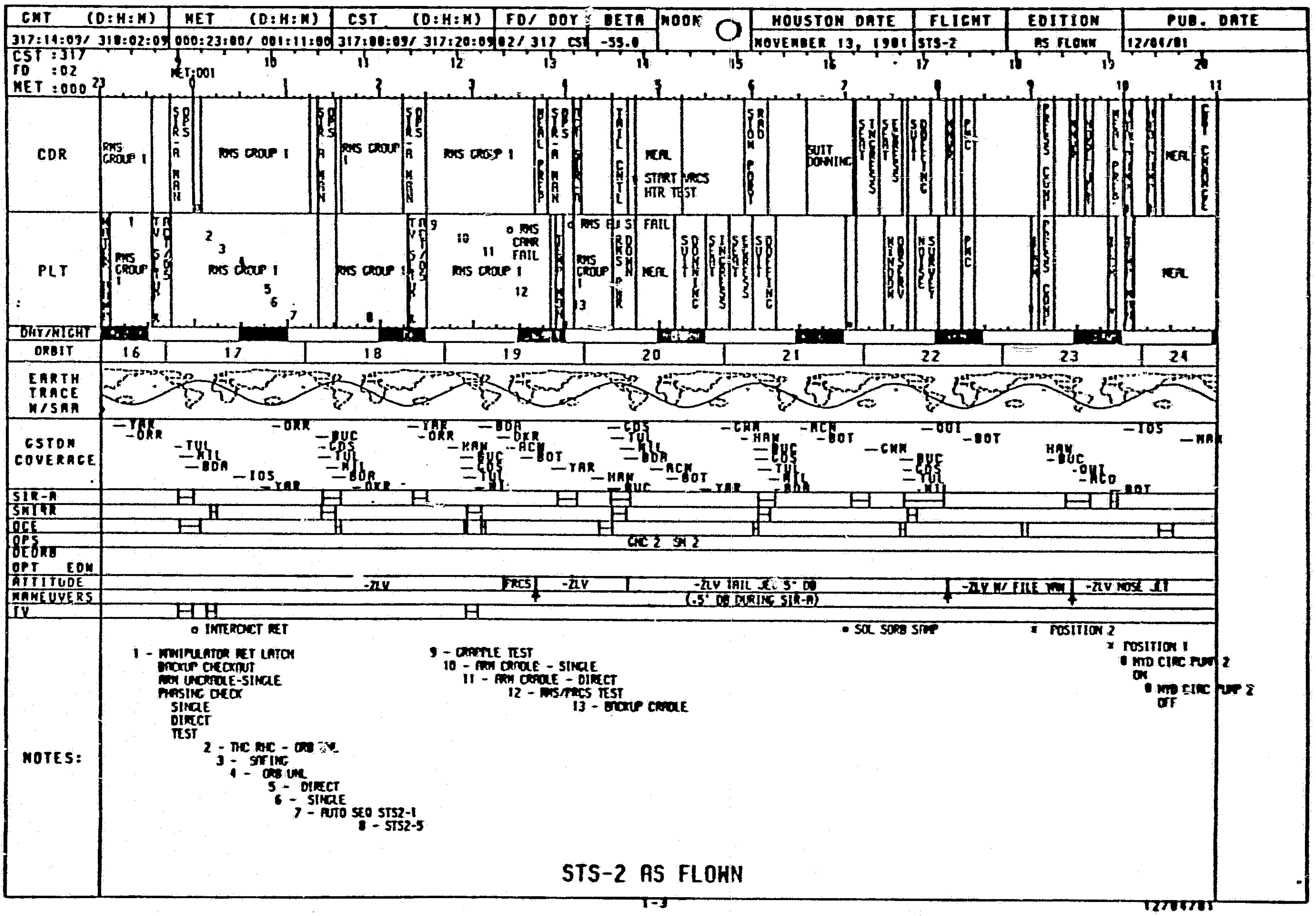
TABLE II-1. Continued

GMT (D:H:M)	MET (D:H:M)	CST (D:H:M)	FD/ DOY	BETA	MOON	HOUSTON DATE	FLIGHT	EDITION	PUB. DATE
317:02:09/ 317:14:09	000:11:00/ 000:23:00	316:20:09/ 317:08:09	01/ 316 CST	-53.9		NOVEMBER 13, 1981	STS-2	AS FLOWN	12/04/81



5

TABLE II-1. Continued



ORIGINAL PAGE IS OF POOR QUALITY

TABLE II-1. Continued

CMT (D:H:M)	MET (D:H:M)	CST (D:H:M)	FD/ DOY	BETA	MOON	HOUSTON DATE	FLIGHT	EDITION	PUB. DATE
318:02:09/ 318:14:09	001:11:00/ 001:23:00	317:20:09/ 318:08:09	02/ 317 CST	-55.7		NOVEMBER 14, 1981	STS-2	AS FLOWN	12/04/81

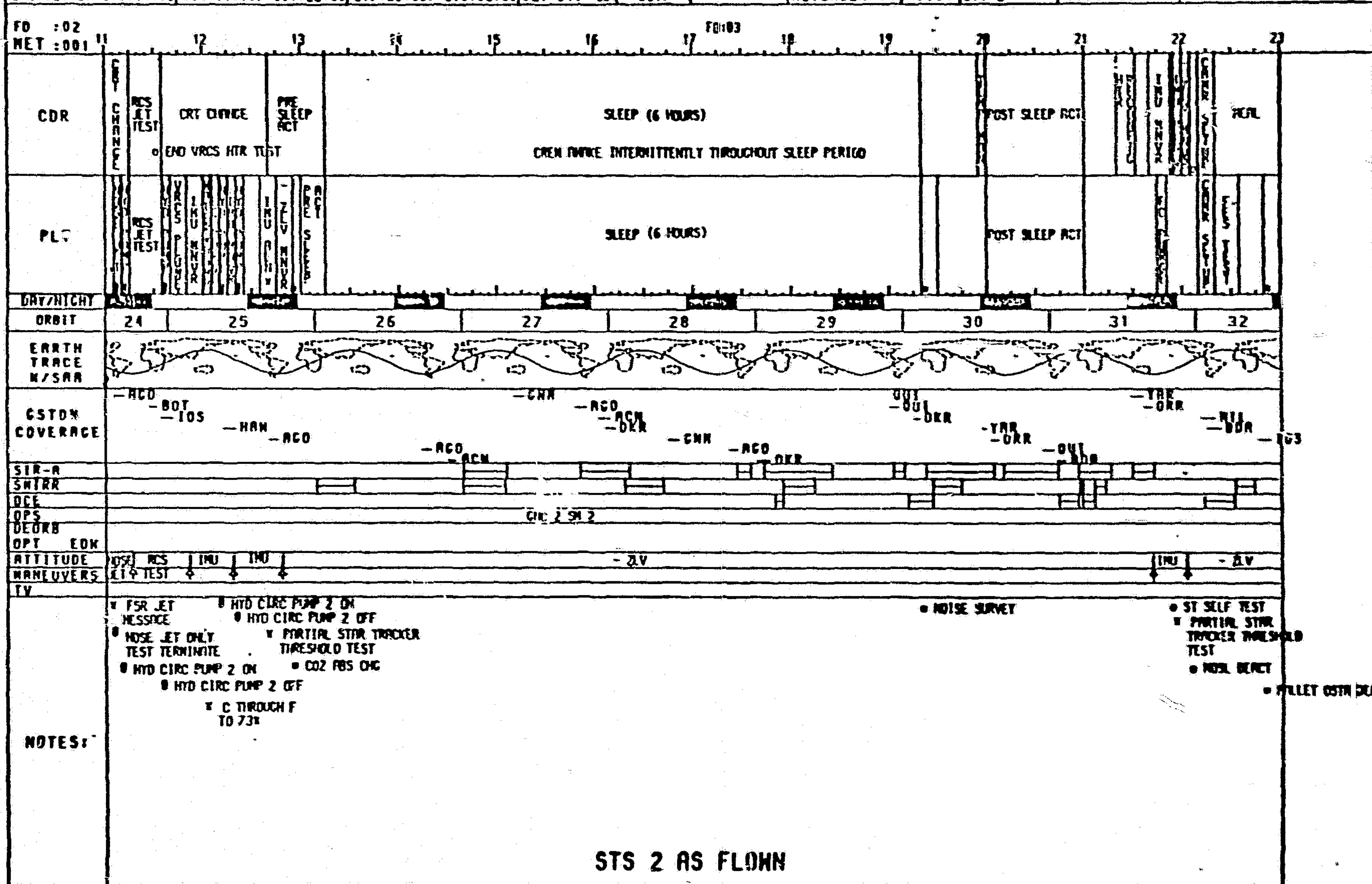
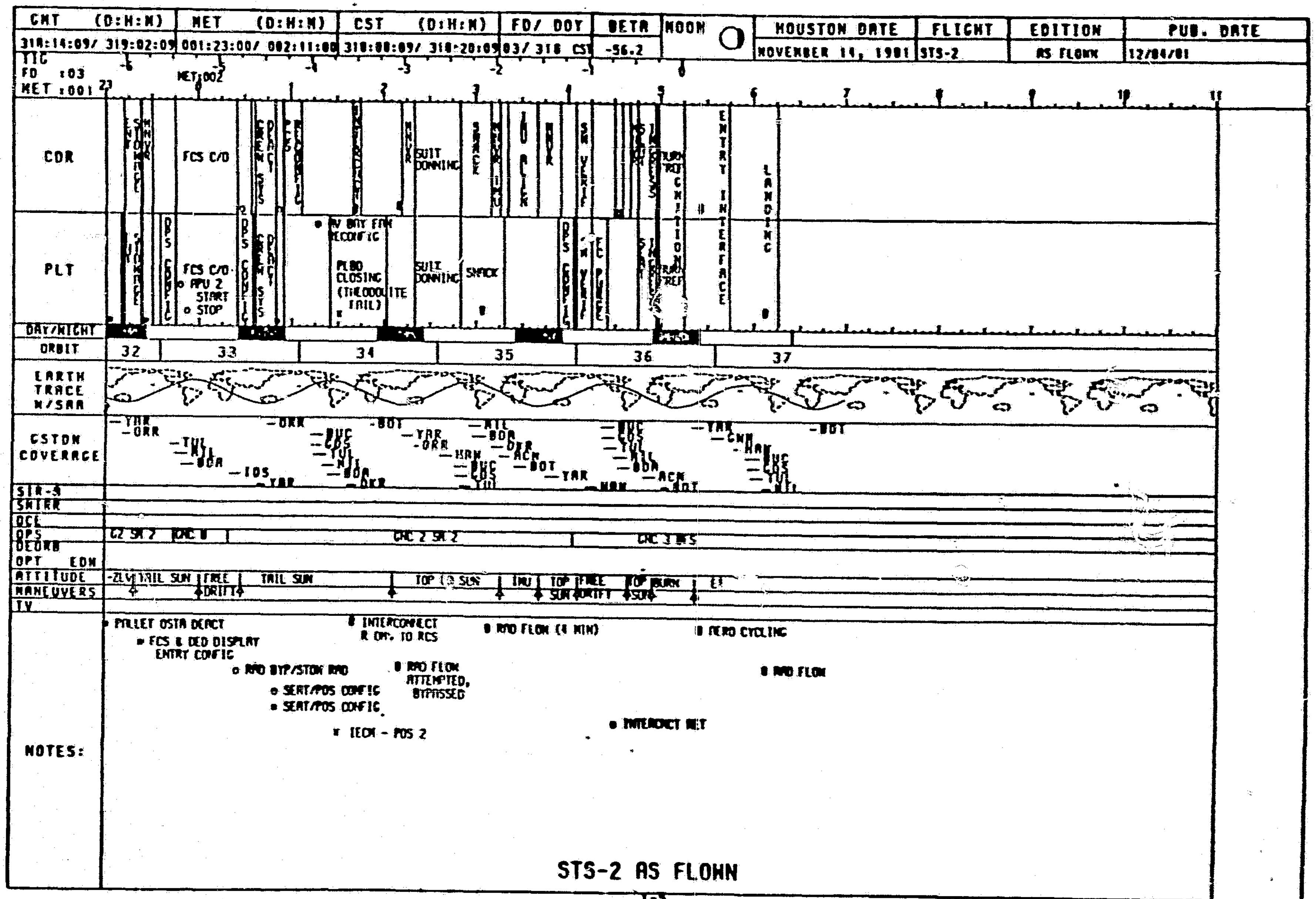


TABLE II-1. Concluded



12/04/81

TABLE II-2. STS-2 AS-FLOWN ATTITUDE TIMELINE

COMMENT	TIME GMT/MET	MODE	MATRIX	ATTITUDE ROLL	PITCH	YAW
PRE-LAUNCH		LVLH		180.00	0.00	0.00
NOM OMS 1 ATT	316:15:20:00 0:00:10:00	IH	MIR401	322.10	340.40	356.10
NOM OMS 2 ATT	316:15:42:00 0:00:32:00	IH	MIR401	27.10	113.00	332.20
-ZLV YPOP ATT	316:16:25:00 0:01:15:00	LVLH		180.00	0.00	0.00
COAS CAL ATT	316:17:40:00 0:02:30:00	IH	MIR401	79.40	95.70	307.30
IMU ALN ATT	316:17:50:00 0:02:40:00	IH	MIR401	73.30	88.19	307.00
-ZLV YPOP ATT	316:19:25:00 0:04:15:00	LVLH		180.00	0.00	0.00
OMS 3A BURN ATT	316:22:45:00 0:07:35:00	IH	MIR401	336.00	17.00	319.00
OMS 3B BURN ATT	316:22:57:00 0:07:47:00	IH	MIR401	336.00	16.50	319.00
OMS 4 BURN ATT	316:23:30:00 0:08:20:00	IH	MIR401	29.50	184.10	35.20
-ZLV YPOP ATT	317:00:20:00 0:09:10:00	LVLH		180.00	0.00	0.00
IMU ALN ATT	317:02:10:00 0:11:00:00	IH	MIR401	268.40	194.90	24.60
ATTITUDE HOLD	317:02:47:00 0:11:37:00	IH	MIR401	310.00	195.00	24.60
-ZLV YPOP ATT	317:03:45:00 0:12:35:00	LVLH		180.00	0.00	0.00
IMU ALN-THLD ATT	317:13:05:00 0:21:55:00	IH	MIR401	268.40	194.90	24.60
-ZLV YPOP ATT	317:13:28:00 0:22:18:00	LVLH		180.00	0.00	0.00
-ZLV ATT BIAS	317:23:15:00 1:08:05:00	LVLH		180.00	0.00	25.00
-ZLV YPOP ATT	318:00:40:00 1:09:30:00	LVLH		180.00	0.00	0.00
RCS JET TEST	318:02:25:00 1:11:15:00	IH	MIR401	38.00	143.00	358.00
IMU ALN ATT	318:03:10:00 1:12:00:00	IH	MIR401	79.00	149.00	357.80

TABLE II-2. Concluded

COMMENT	TIME GMT/MET	MODE	MATRIX	ATTITUDE ROLL	PITCH	YAW
2ND THLD ALN ATT	318:03:35:00 1:12:25:00	IH	MIR401	28.10	252.70	9.90
-ZLV YPOP ATT	318:04:05:00 1:12:55:00	LVLH		180.00	0.00	0.00
IMU ALN ATT	318:13:01:00 1:21:51:00	IH	MIR401	268.40	194.90	24.60
-ZLV YPOP ATT	318:13:17:00 1:22:07:00	LVLH		180.00	0.00	0.00
TAIL SUN ATT	318:14:31:00 1:23:21:00	IH	MIR401	15.50	49.60	10.30
FREE DRIFT	318:15:10:00 2:00:00:00	IH	MIR401	356.40	60.30	2.00
FREE DRIFT	318:15:31:00 2:00:21:00	IH	MIR401	18.20	51.70	16.70
TAIL SUN ATT	318:15:35:00 2:00:25:00	IH	MIR401	96.50	49.50	16.20
TOP SUN ATT	318:17:38:00 2:02:28:00	IH	MIR401	318.30	101.20	298.00
IMU ALIGN ATT	318:18:30:00 2:03:20:00	IH	MIR401	243.00	86.00	13.70
IMU VERIF ATT	318:18:45:00 2:03:35:00	IH	MIR401	236.30	93.40	331.00
TOP SUN ATT	318:19:00:00 2:03:50:00	IH	MIR401	198.80	351.70	4.00
FREE DRIFT	318:18:20:00 2:04:10:00	IH	MIR401	220.50	72.50	328.20
TOP SUN	318:19:52:00 2:04:42:00	IH	MIR401	198.80	351.70	4.00
DEORB ATT	318:20:09:00 2:04:59:00	IH	MIR401	138.30	355.30	13.00
MM 303 ENTRY	318:20:28:12 2:05:18:12	IH	CURI01	202.24	194.72	34.72
MM 304 ENTRY	318:20:45:38 2:05:35:38	LVLH		1.41	38.85	358.25

MATRIX ID "MIR401" and "CURI01" = TRANSFORMATION FROM MEAN-OF-1950 to ADI

$$\begin{matrix} 1.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 1.0 \\ 0.0 & -1.0 & 0.0 \end{matrix}$$

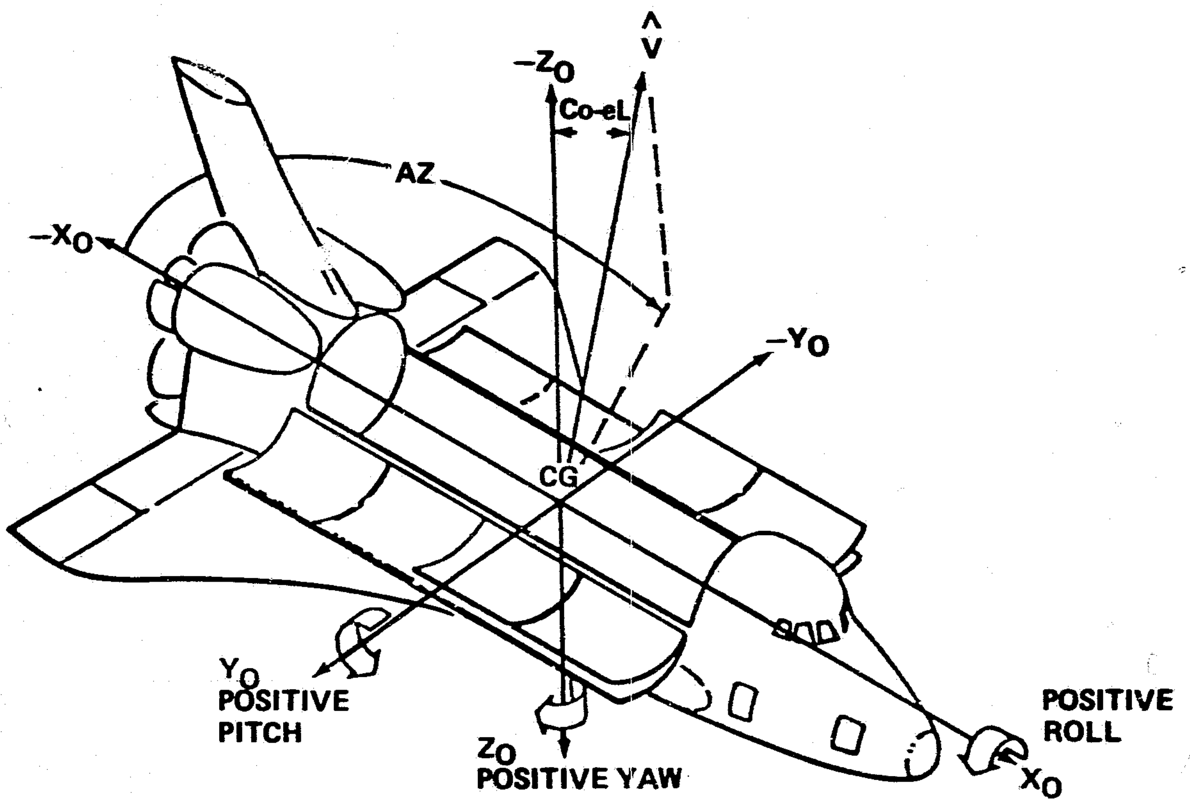


Figure II-1. Orbiter body coordinate system and azimuth, co-elevation coordinates.

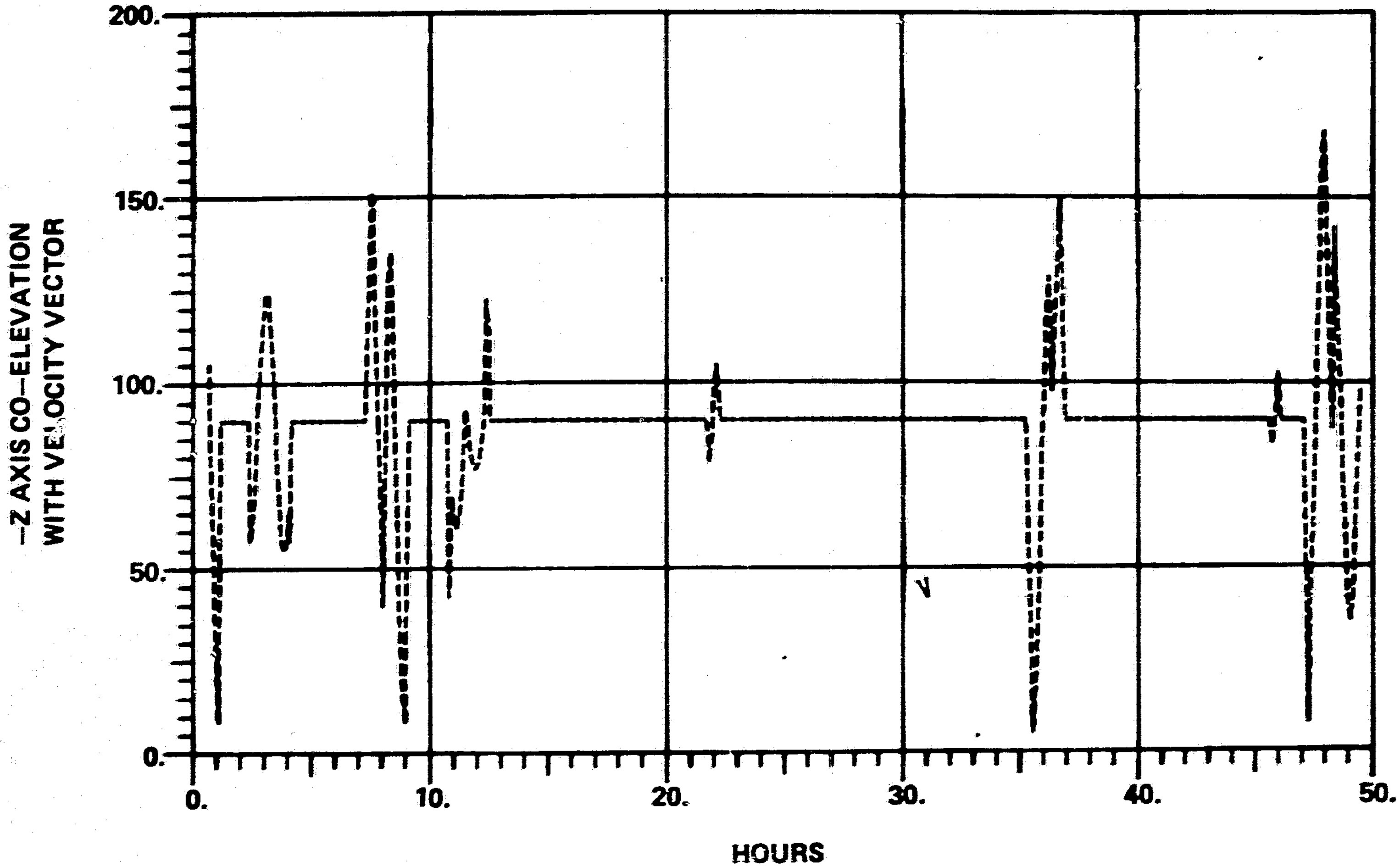


Figure II-2. STS-2 Mission Elapsed Time (MET).

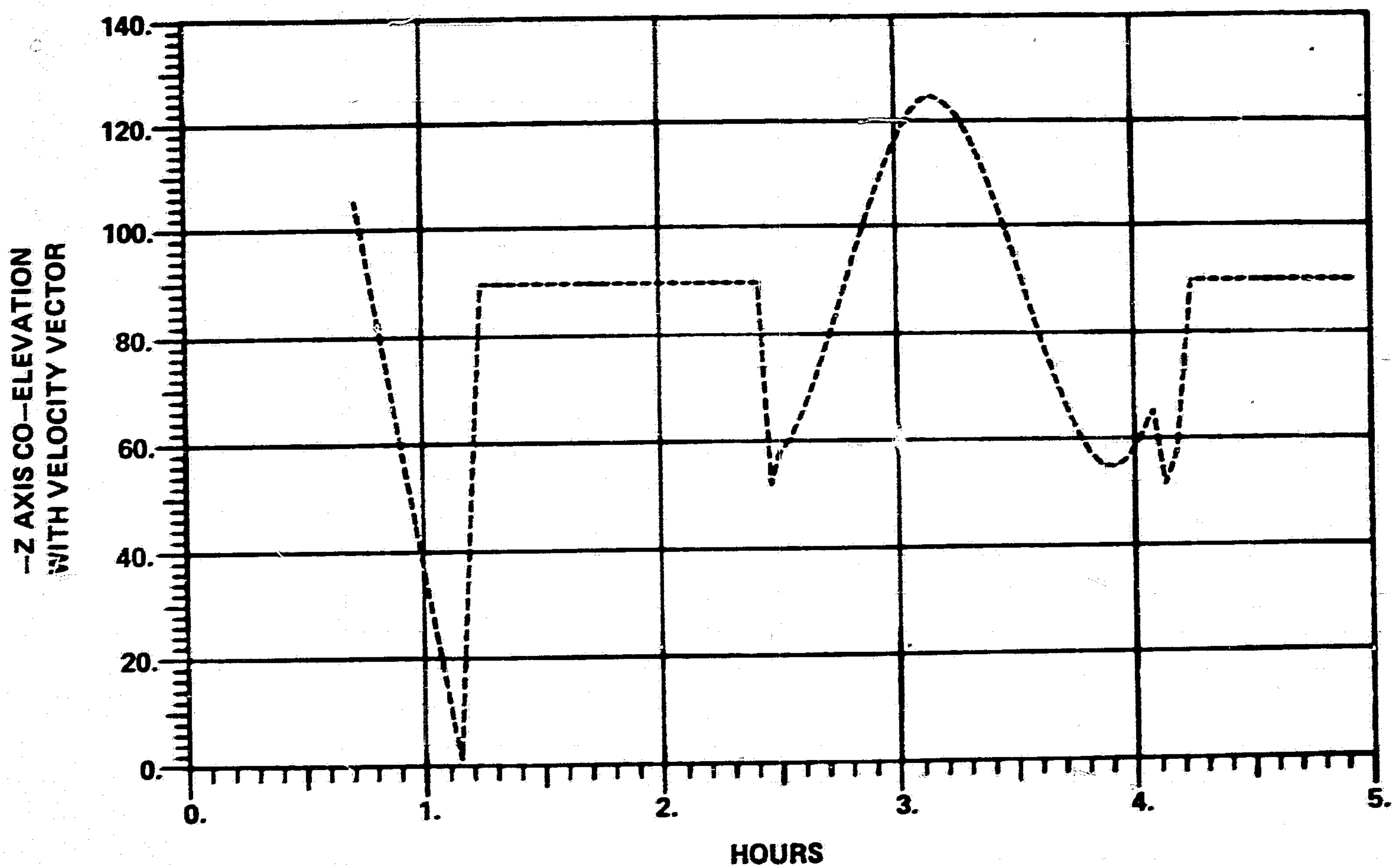


Figure II-3. STS-2 MET (0-5).

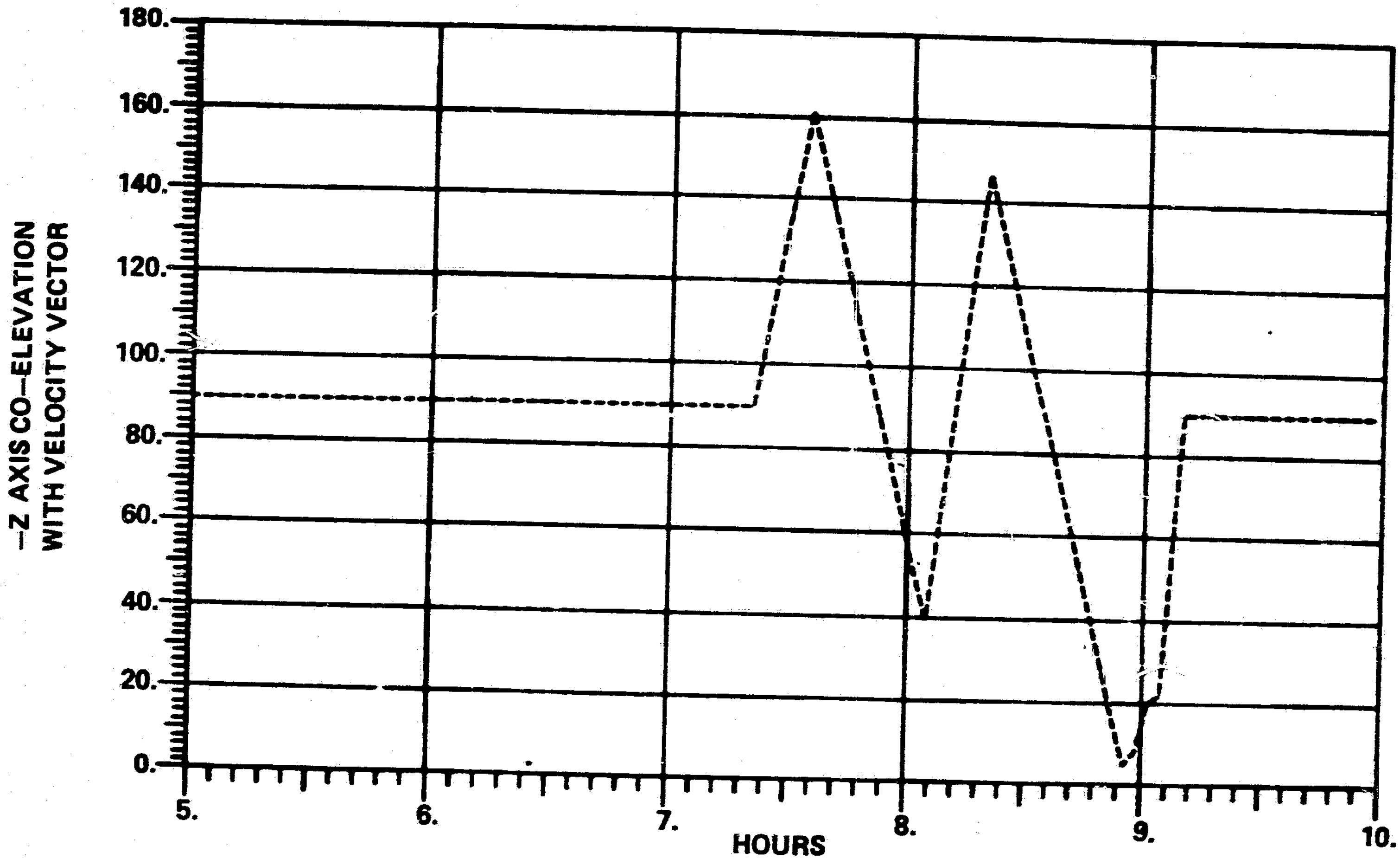


Figure II-4. STS-2 MET (5-10).

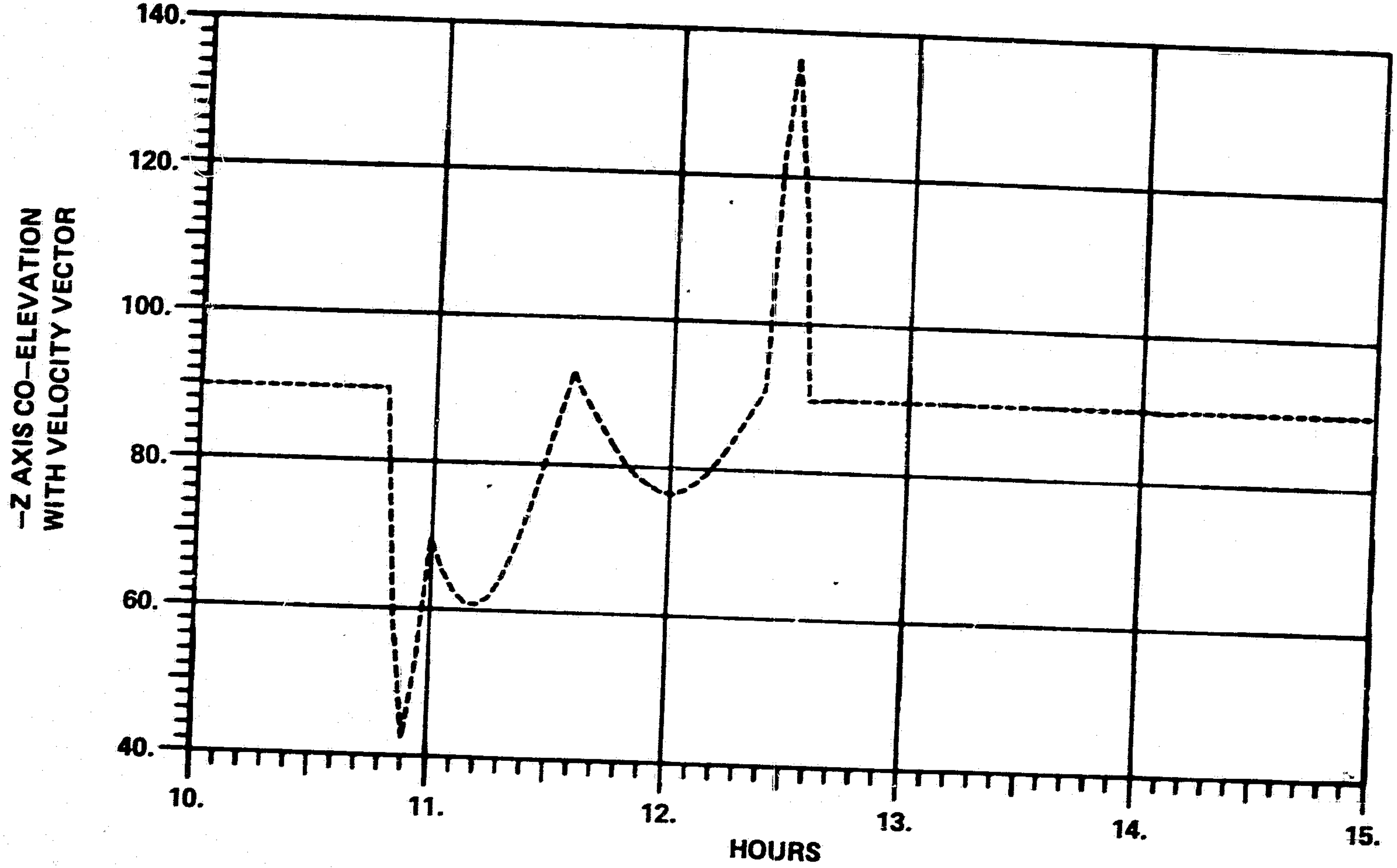


Figure II-5. STS-2 MET (10-15).

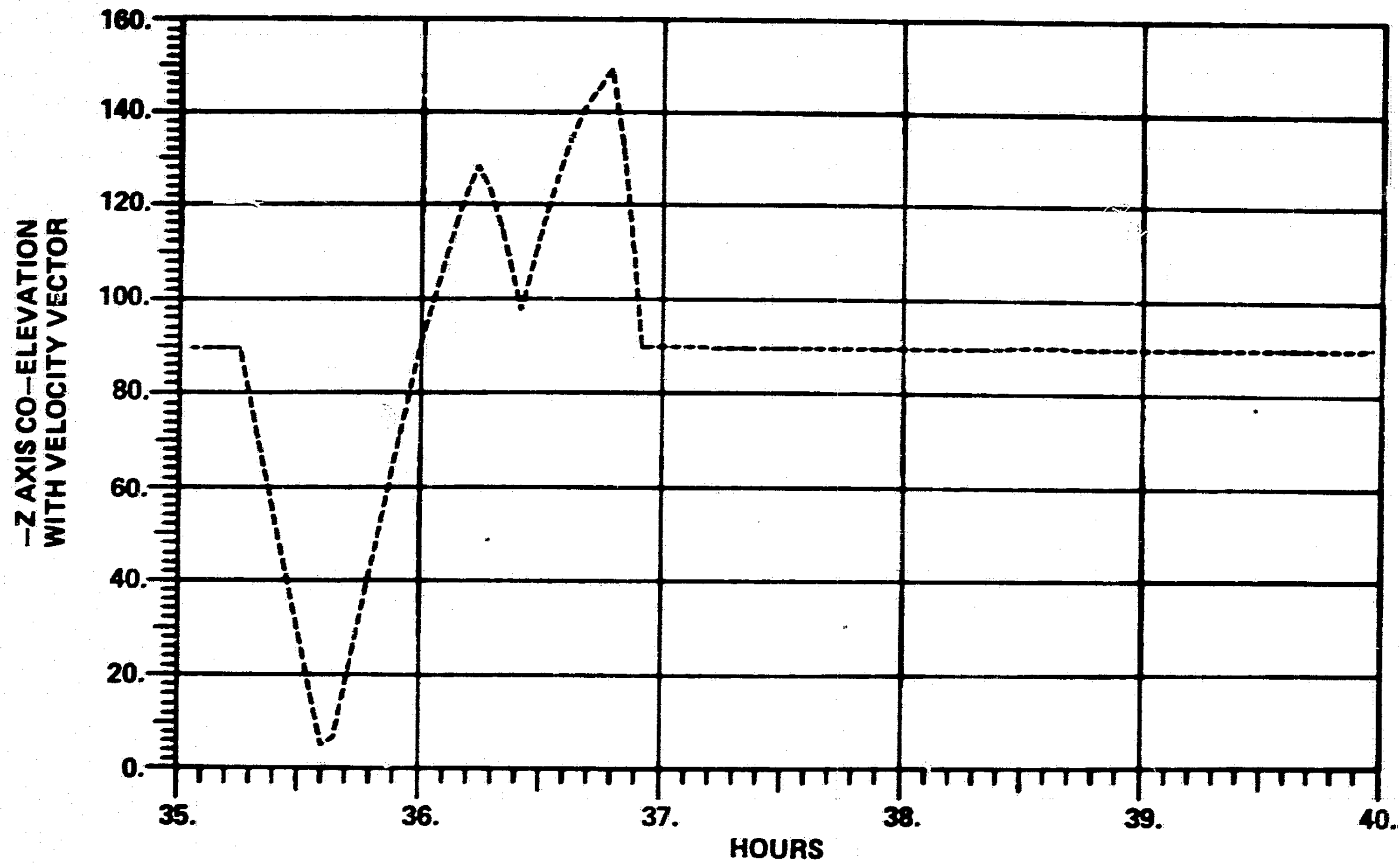


Figure II-6. STS-2 MET (35-40).

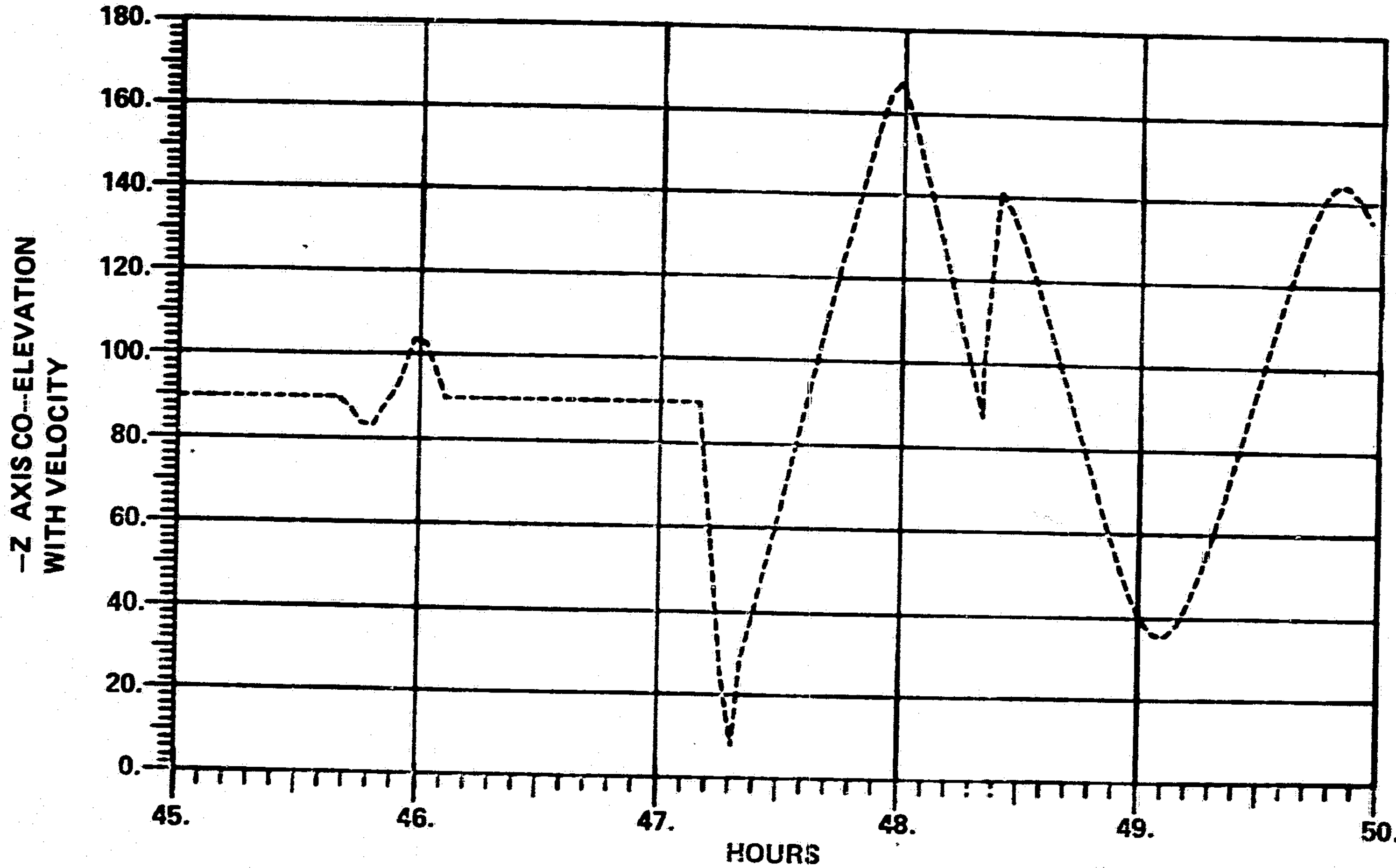


Figure II-7. STS-2 MET (45-50).

III. IECM ENGINEERING SUBSYSTEMS PERFORMANCE ON STS-2

L. W. Russell and W. C. Claunch*

During the STS-2 mission, the IECM engineering subsystems performed as planned with only one known anomaly, that being a low battery voltage condition occurring during the descent phase of the IECM operation. The major components of the engineering subsystems are: (1) Data Acquisition and Control System (DACS), (2) Power Distribution and Control Unit (PD&CU), (3) Flight Batteries, and (4) Thermal Control System.

The DACS is a programmable, microprocessor-based data system that performs several distinct functions: (1) sampling analog and digital data from IECM instruments and subsystems, (2) formatting data for storage on the IECM data recorder, and (3) sequencing and control of IECM instruments and subsystems. The calibration of the DACS analog and digital data channels was verified by testing before and after the STS-2 mission. The STS-2 IECM flight data, approximately six million bits, was time-tagged and stored as a serial bit stream on the IECM flight data recorder. These data were recovered when the IECM was returned to the Marshall Space Flight Center (MSFC) to be refurbished for STS-3.

The PD&CU consists of two modules: the power distributor and the voltage regulator. The voltage regulator supplies a constant 28 V d.c. to the IECM regardless of whether the input power source is the internal flight batteries (used during ascent and descent operations) or the Orbiter Payload Aft Main B power bus (used during on-orbit operations). The power distributor has two major functions: (1) providing switched 28 V d.c. power to IECM instruments under control of the DACS and (2) interfacing the IECM with Orbiter MDM commands, the IECM switch (Panel R11A1, switch 2), and the IECM T - 0 umbilical disconnect signal. Additionally, the power distributor monitors the voltage of the IECM batteries and sets a low-battery status signal to the DACS when the batteries discharge to a 23 V d.c. level. The calibration of this voltage-sensing circuit was verified by testing before and after the STS-2 mission. Table III-1 provides a summary of the mission times at which various events were detected by the power distributor. The mission time is given as IECM Clock Time (IECMCT), as Mission Elapsed Time (MET), and as Universal Time (UT) for the STS-2 mission. The IECM Clock Time is an internal elapsed time clock that starts counting when the IECM T - 0 umbilical disconnect signal is detected. This counter is incremented once per minute and is reset any time power to the IECM is lost.

The IECM flight battery subsystem consists of four 18 amp-hour lithium carbon monofluoride primary batteries paralleled to form an internal IECM 28 V d.c. battery bus with a total energy capacity of 72 amp-hours. The batteries supply power to the IECM for ascent, descent,

* Structures and Propulsion Laboratory, NASA/MSFC

and postlanding operations. Each battery has two temperature sensors which are monitored by the DACS. During the STS-2 flight, these temperatures varied between 16.8°C and 24.4°C, which was well within design limits. As mentioned earlier, a battery low-voltage sensing circuit in the power distributor is used to alert the DACS that the batteries have discharged to a 23 V d.c. level. When the DACS receives this signal, it dumps all data buffers to the tape recorder and then attempts to switch the IECM to the Orbiter 28 V d.c. power bus. As seen in Table III-1, a battery low-voltage signal was detected during the STS-2 IECM descent operation at approximately 36 min after the de-orbit command was received by the IECM. At this point, the batteries should have had approximately 20 amp-hours of capacity remaining, according to records of flight and preflight test usage of the batteries. Since the operation and calibration of the battery voltage-sensing circuitry in the Power Distributor was verified before and after the STS-2 mission in IECM functional tests, it appears that the battery system did not deliver the full 72 amp-hours of energy as designed. This unexpected event was the only known anomaly in the performance of the IECM engineering subsystems during the STS-2 flight. The causes of this anomaly are currently being analyzed at MSFC.

IECM thermal control is accomplished with a semi-passive system that is designed to reject solar heat input and to provide internal heat to the IECM when required. The top, sides, and bottom of the IECM are isolated from the external environment by radiation panels, which are themselves isolated from each other and the internal IECM structure by low-conductance fiberglass spacers. The external coating of the IECM is S-13G-LO paint which produces a low solar absorptance surface while providing good radiation coupling to the external environment for heat rejection during hot conditions. Most of the IECM instruments and subsystem components are mounted directly on the thermal baseplate, which is designed to operate between 0°C and 70°C. The instruments are designed to maximize thermal conduction coupling to this baseplate. The baseplate has nine temperature sensors which are monitored by the DACS. The lower thermal limit of the baseplate is maintained by nine resistive heaters which are divided into two zones, with zone A providing 115 watts of power and zone B providing 69 watts. The DACS controls these heaters by sampling the temperatures in each zone. Two temperature sensors in a particular zone must reach 4.4°C before the respective bank of heaters turns on. Turn-off of the heaters occurs when two temperature measurements of a zone reach 10°C. Preflight analysis indicated that the maximum instrument temperatures should have been in the 25°C to 35°C range. The inflight recorded data included the baseplate temperature measurements, the battery temperatures, and a number of housekeeping temperature measurements in the various instruments. The results from this instrumentation are shown in Table III-2 and indicate that the temperatures were all within acceptable limits. The maximum values fell within the predicted range from the preflight analysis. As can be seen in Table III-2, the heaters were not required for this mission.

TABLE III-1. SUMMARY OF IECM MISSION EVENT TIMES

Event	IECMCT	MET	UT
1. IECM Launch Command	0 00:00:00	0 00:00:00	316 15:05:30
2. T-0 Disconnect Ascent Mode	0 00:00:00	0 00:00:00	316 15:10:00
3. On-Orbit Command	0 00:37:00	0 00:37:00	316 15:47:00
4. IECM Mass Spectrometer On	0 03:25:00	0 03:25:00	316 18:35:00
5. Start IECM Gas Release	1 09:10:00	1 09:10:00	318 00:20:00
6. Stop IECM Gas Release	1 09:05:00	1 09:05:00	318 00:55:00
7. Aft Main B Orbiter Power Off*	1 10:00:00	1 10:00:00	318 01:10:00
8. Aft Main B Orbiter Power On	0 00:00:00	1 12:42:00	318 03:52:00
9. De-Orbit Command	0 16:53:00	2 05:34:51	318 20:44:51
10. Low Battery Voltage Detected	0 17:29:00	2 06:10:51	318 21:20:51
11. Aft Main B Orbiter Power Off	0 18:18:00	2 06:59:51	318 22:09:51

*An additional 25 min of IECM data was lost in buffer storage at the time of power off.

TABLE III-2. SUMMARY OF STS-2 IECM COMPONENT TEMPERATURES

COMPONENT	DESIGN LIMITS MIN. (°C)	MAX. (°C)	STS-2 RESULTS MIN. (°C)	MAX. (°C)
Camera	0	60	13	25
Power Distributor	0	70	*	*
TQCM Electronics	0	70	*	*
Voltage Regulator	0	70	*	*
Optical Effects Module	0	70	18	30
Mass Spectrometer	0	70	*	*
Batteries	0	74	16.8	24.4
CQCM Electronics	0	70	*	*
Tape Recorder	0	65	*	*
Cascade Impactor	0	70	*	*
CQCM	-200	80	-52.11	+30.27
Passive Sample Array	-45	100	11.2	35.9
DACS	0	70	*	*
Baseplate	0	70	15.3	35.2

* No flight temperature measurements available for these components. However, most of these items had a baseplate temperature sensor located adjacent to them. These temperatures were all within acceptable limits.

IV. HUMIDITY MONITOR AND DEW POINT HYGROMETER

H. W. Parker

The Humidity Monitor measured zero relative humidity during ascent, reflecting the environment provided by the cargo bay dry nitrogen gas purge prior to launch. The Dew Point Hygrometer correspondingly indicated a dew point below its measuring range of -6.7°C (20°F).

The results of relative humidity and temperature measurements during descent are shown in Figure IV-1. The air pumps were timed to turn on at approximately 22.875 km (75,000 ft) and remained on until approximately 30 min after landing. The relative humidity rose to a near constant level of approximately 15 percent at a temperature of 18° to 20°C. The dew point remained below -6.7°C.

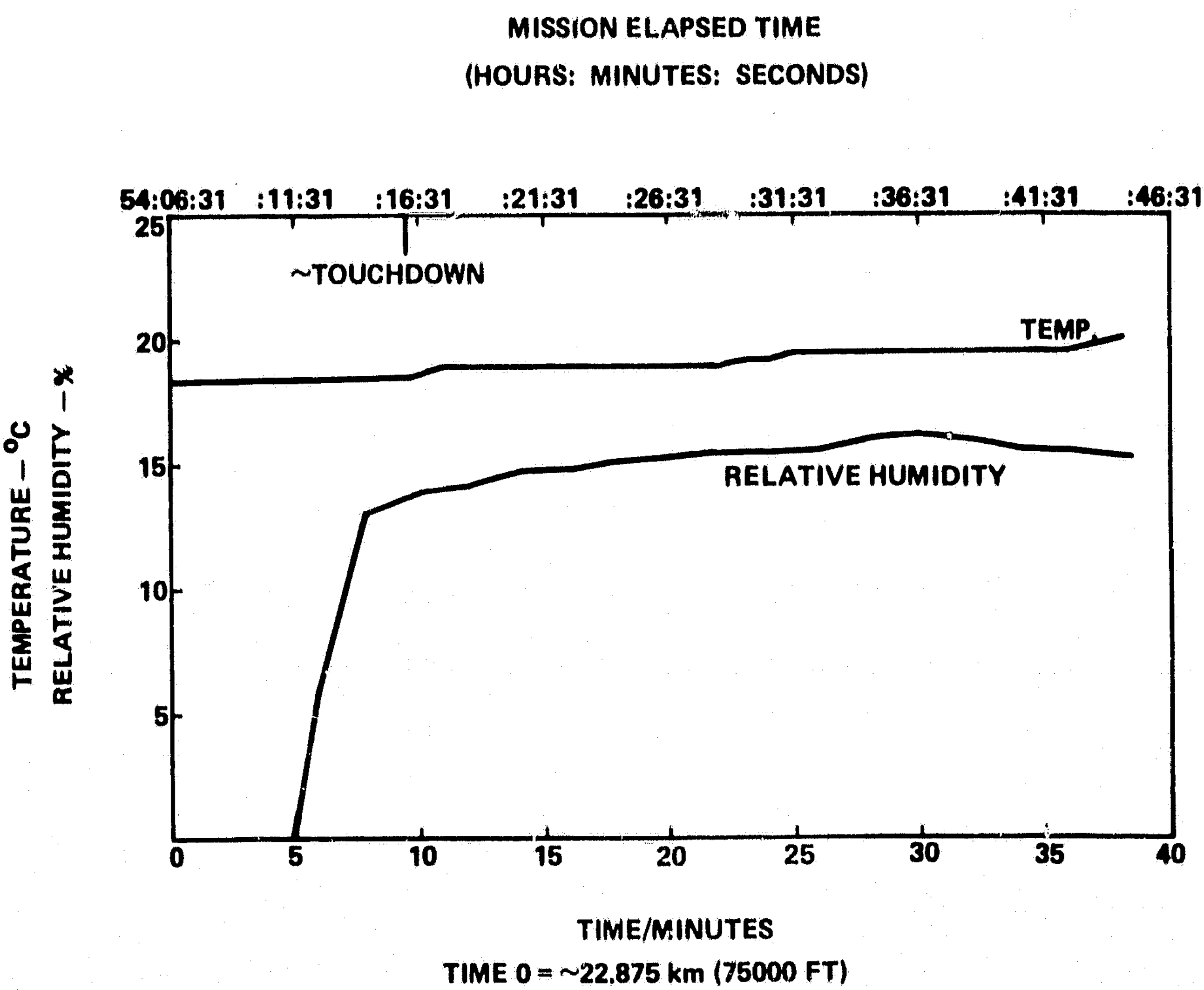


Figure IV-1. Relative humidity and temperature during descent of STS-2.

V. AIR SAMPLER

P. N. Peters and H. B. Hester

The Air Sampler was designed for a number of functions. These can be classified as: ground sampling, ascent sampling, and descent sampling. In accordance with the Contamination Working Group requirements, the ground sampling measured condensibles (vapors of hydraulic fluids, solvents, etc.), the ascent sampling measured condensibles and HCl, and the descent sampling measured reactive compounds of nitrogen; in addition, descent condensibles and other species were measured with slight modifications of the measurement procedures. Finally, separate pressure measurements were made outside the bottles (approximately the cargo bay environment; shown in Figures V-1 and V-2 for ascent and descent) and inside the pumping manifold every 10 s to assist in throughput determinations. Condensible analysis is performed by gas chromatography/mass spectroscopy (GC/MS) measurements, sensitive to parts per billion (ppb) for some species. The reactive species are determined by analysis of specifically reacted surfaces. The lower limits for reproducible measurements are 2 $\pm$ 2 ppm for HCl, 50 $\pm$ 10 ppm for NO and NO_2, and 10 $\pm$ 10 ppm for NH_3. Electron spectroscopy for chemical analysis (ESCA) is used as part of the analysis for reactives.

The Air Sampler results indicate the presence of solvent vapors during ground activities in the OPF to be variable with time. Approximately 50 separate species were observed. Maximum total quantity in any one sample translated to less than 3 ppm and was probably due to tile bonding and debonding activities; mostly solvents were observed. Improvements were noted from STS-1 to STS-2. A residual gas analysis of air retained in a descent bottle indicated less than 100 ppm of hydrogen. Pressure in the IECM was measured and is plotted; because of good venting between the IECM interior and the STS, this pressure should be fairly representative of the cargo bay pressure. The rapid venting of pressure during ascent supports the finding of no HCl on the reactive samples. Initial indications are that little or no reactive nitrogen species were collected during descent. Complete analysis of STS-2 condensibles during ascent is not available as of this writing; however, residual gas analyses of the bottles prior to removal of samples did not show excessive cracking fractions below 100 amu.

A typical ground sampling of the OPF environment contained solvent vapors, with the lowest concentrations observed falling within levels typically found in urban environments (fractional parts per million); higher levels of less than 3 ppm were also observed. Total masses retained varied from approximately 8 μg to 69 μg, and as many as 50 compounds or classes were identified. The ground sampling by the IECM was necessarily temporally and spatially limited. The presence of higher concentrations of solvents might be expected if the cleaning of surfaces and bonding and debonding of protective tiles are being performed.

Analyses of the reactive samples indicated no detectable reaction with HCl during ascent and very little, if any, reaction with nitrogen compounds during descent (after long counting times, only one suggestion of a possible peak was observed in the ESCA spectra). An oxygen peak was observed in the analysis of the same ruthenium compounds, suggesting hydroxyl formation (hydrogen is not detected).

An anomaly in performance of the sampling was detected. The normally open pyrovalves on bottle number 2 fired on schedule during ascent but did not provide the high-integrity seal that was expected. The valve on the inlet has been found to leak at one section of the perimeter of its sealing surface. A failure analysis is being performed on this valve. The purpose of the high-integrity seals was to assure no escape of condensibles after reaching the vacuum in orbit. Since temperature sensors on another experiment indicated that the IECM never reached 100° F on this mission, there is reasonable confidence that most of the species remained on the adsorbents. Also, repressurization during descent filled the bottle, but the gas was not pumped through the adsorbent; thus, any adsorption of descent condensibles occurred only by diffusion through the adsorbent tubes, which have very limited conductances. It is believed that samples from bottle number 2 should thus have reasonable validity for ascent analysis, especially after comparison with the results for descent sampling.

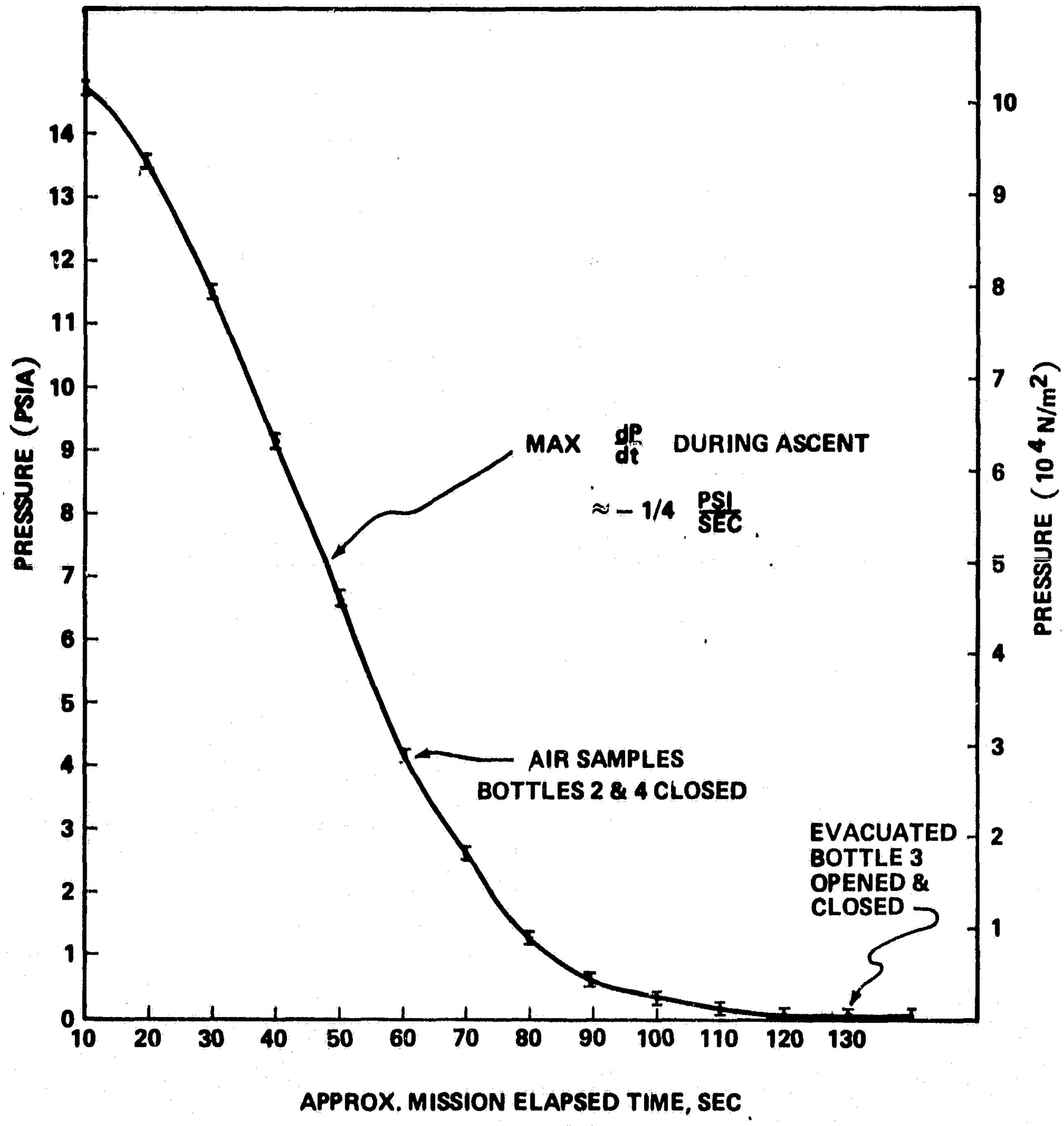


Figure V-1. Pressure during ascent, measured inside IECM cover.

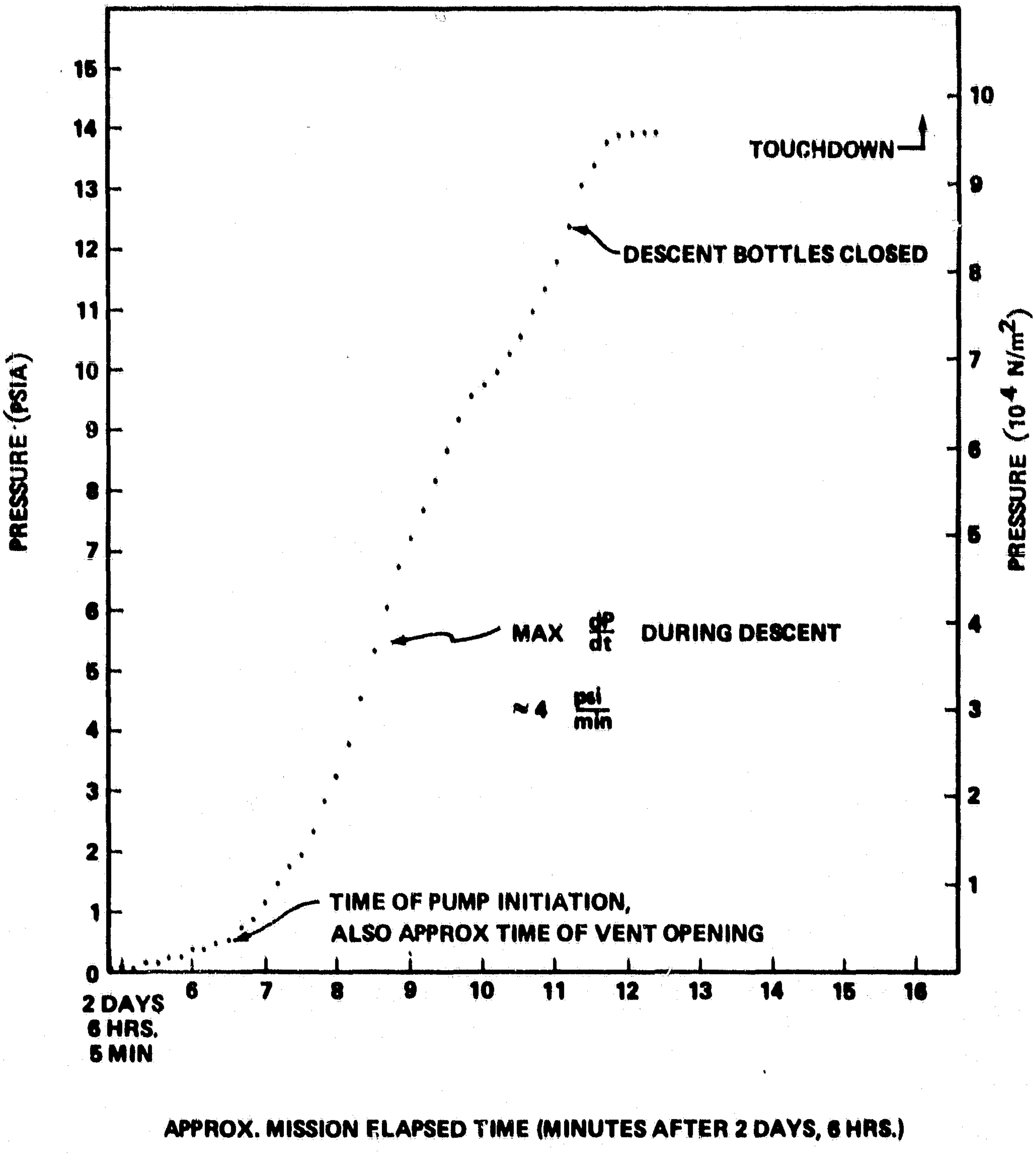


Figure V-2. Pressure during descent, measured inside IECM cover.

VI. CASCADE IMPACTOR

B. J. Duncan

Volumetric concentrations of suspended particulates were measured by the Cascade Impactor during ascent and descent phases of the STS-2 mission. The resultant instantaneous concentrations are plotted as a function of mission time in Figure VI-1. Mass concentrations were much higher for the smaller size particulates, with the 5-micrometer and larger particles showing concentrations of approximately 30 $\mu g/m^3$ or less. Making assumptions for density and mean size of $\rho = 2\ g/cm^3$ and $d = 10$ micrometers, respectively, this mass concentration measurement translates to approximately 3×10^4 particles/m^3. Within the accuracies involved, this meets the Contamination Requirements Definition Group (CRDG) goal of an equivalent 100 K clean room environment.

The smaller sized particles showed significantly higher mass concentrations, peaking in the 1- to 5-micrometer range at approximately 1350 $\mu g/m^3$ during ascent and approximately 700 $\mu g/m^3$ during descent. Somewhat lower concentrations are indicated for particles less than 1 micrometer in size, 700 $\mu g/m^3$ and 180 $\mu g/m^3$, respectively, during ascent and descent. However, the concentration measurements for these smallest size particles should be considered only as a lower limit because the stage was operating near saturation, with reduced collection efficiency.

In addition to ascent and descent particulate measurements, the Cascade Impactor was operated during the prelaunch phase in the Operations and Checkout area, the OPF area, and during the approximately 11-hr hold on the pad at KSC. Figure VI-2 shows postflight photographs of the sensor crystal for each stage. The relative sparsity of 5-micrometer and larger particles may be qualitatively compared with the 1- to 5-micrometer particles in the center photograph. Saturation of the 0.3- to 1-micrometer stage is evident in the photograph at the right. The majority of these particles were, of course, collected during prelaunch operations, principally during the hold, due to the relatively longer operating times. These samples will be analyzed for particle size distribution and elemental content of particulates collected during operation in prelaunch and mission environments.

Nonvolatile residue at ambient temperature was measured throughout the mission and is still being analyzed.

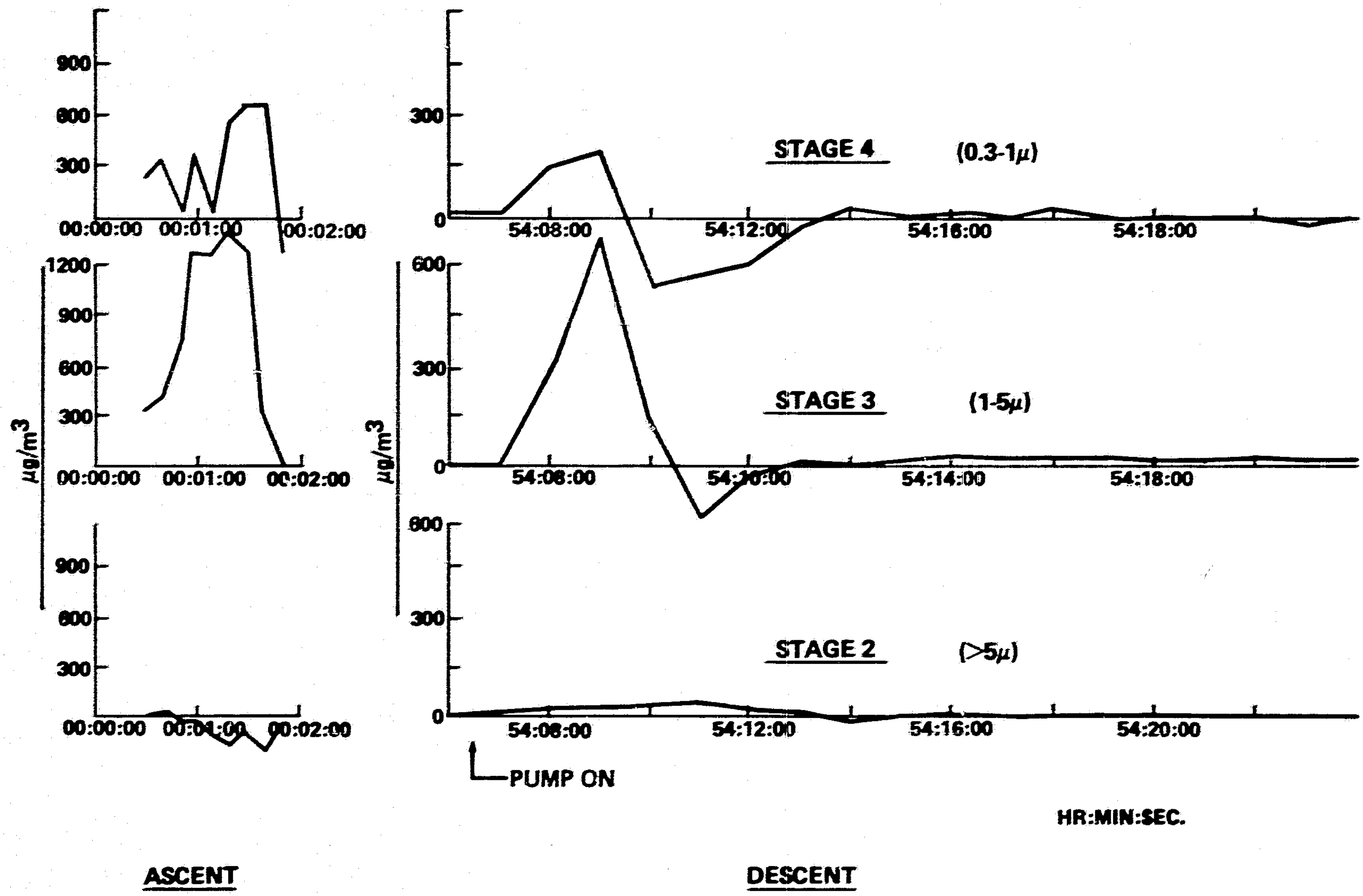
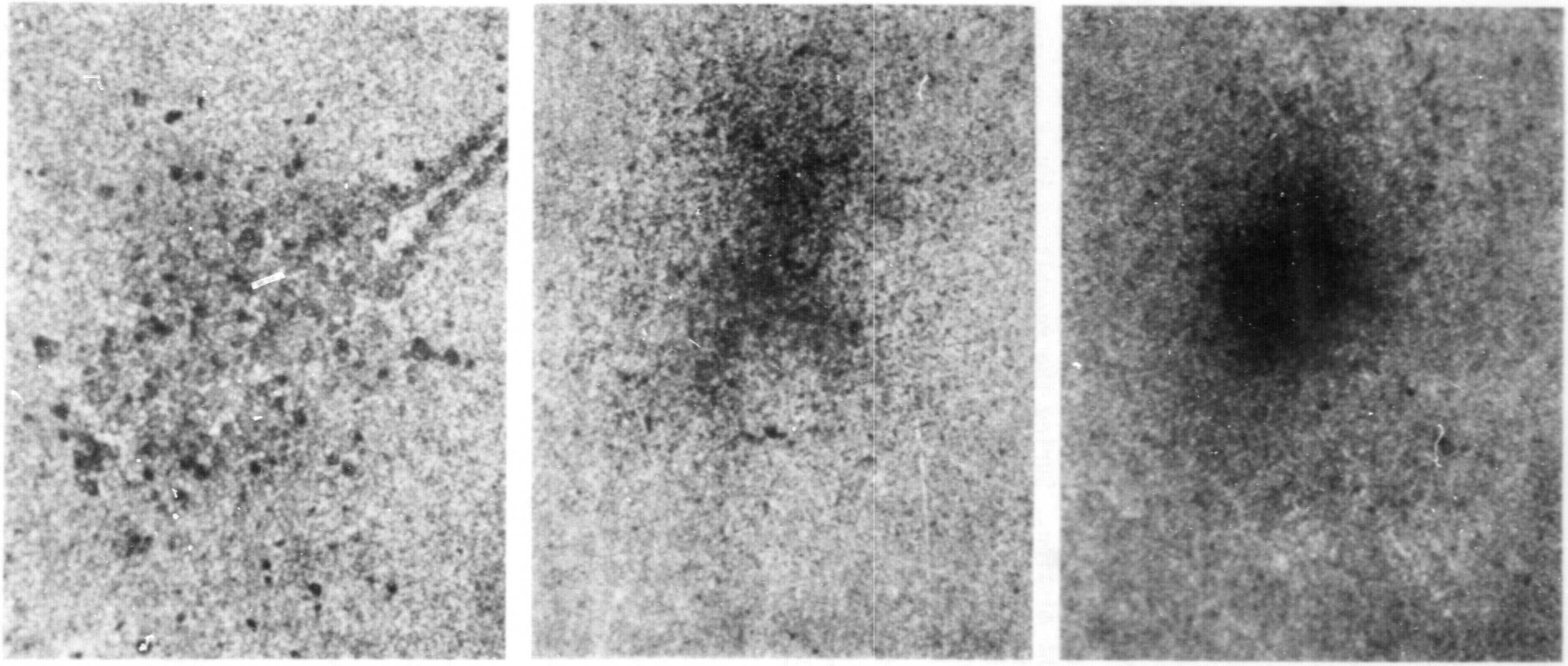


Figure VI-1. Mass concentrations as a function of mission time.



Stage 2 ($>5\mu$) | Stage 3 ($1-5\mu$) | Stage 4 ($0.3-1\mu$)

10μ

Figure VI-2. Cascade sensor crystal (100 X).

VII. OPTICAL EFFECTS MODULE AND PASSIVE SAMPLE ARRAY

R. C. Linton and M. Susko

A. Optical Effects Module

The Optical Effects Module (OEM) is an active monitor of monochromatic (2537 Å) ultraviolet transmittance and scatter and operates during the orbital phase of the mission. Five optical samples are mounted at equal intervals on the circumference of a carousel that rotates in the Shuttle X-Y plane. A sixth, empty, sample mount is included to provide for self-calibration of the transmission measurements during each operational sequence. A complete OEM sequence includes 500 s of static exposure, followed by a data-generating phase, lasting 77 s, during which the samples are stepped through the internal light-beam-detector path by rotation of the carousel. The sequence is triggered by the IECM power-on command and is repeated regularly throughout the flight mission. During the repetitive 500-s exposure intervals, two of the samples (positions designated I_1 and I_5) are positioned within the instrument housing; the others (I_2, I_3, I_4) are directly exposed to the cargo bay environment for approximately 95 percent of the mission period.

A materials listing of the five OEM samples and a summary of mission results are shown in Figure VII-1. The level of uncertainty for OEM transmittance measurements, established by laboratory investigation, is approximately $\pm$ 1 percent.

Most of the inflight optical change noted for OEM samples occurred within the first 4 hr of the mission (Figure VII-2). Throughout the remainder of the flight, different samples indicate alternate patterns of "clean-up" and continued gradual degradation (Figure VII-3). No definitive conclusions have been obtained from attempts to correlate observed optical change with known events of potential contaminant emission; the levels of change indicated during the shorter time intervals of such events are generally within the limits of measurement uncertainty.

The OEM scatter data provided some indication of increased diffuse reflectance from the samples; particulate contamination would cause such an increase. The data are still being analyzed statistically; therefore, only part of the data, corresponding to the early orbital period, are shown (Figure VII-4). The uncertainty in measuring scatter with the OEM, as shown in Figure VII-4, indicates that the interpretation of point-to-point variations of the levels shown is unreliable.

B. Passive Sample Array

The Passive Sample Array (PSA) is an exposure array of various optical materials. For the ferry-flight phase of the mission, a Passive Optical Sample Array (POSA) unit of additional passive optical materials

was mounted in the Shuttle cargo bay at Dryden and removed with the other payloads at KSC.

The PSA included 42 optical samples of various materials plus 2 KRS-5 crystals and 8 electrets for enhanced chemical identification. A directory of PSA samples is included as Figure VII-5. The KRS-5 crystals and 10 of the optical samples were supplied by the Aerospace Corporation as guest experimenter hardware; no results are presented in this report for these samples.

Samples of the PSA flown on the orbital phase of the mission indicate an average specular degradation of 0 to 2 percent in the spectral region 120 to 300 nm (Tables VII-1 and VII-2). Generally, no significant change was evident for diffuse measurements over the range 250 to 2500 nm (e.g., Figures VII-6 and VII-7). Samples of the POSA unit included only on the ferry flight indicate similar levels of degradation (Table VII-3 and Figure VII-8). These results are generally compatible with the results of the POSA units flown on STS-1 [2].

For a measure of contamination due to the ground operating environment, two of the eight PSA trays were exposed without covers in the OPF at KSC from July 15 to August 3, 1981. On August 3, 1981, these exposed trays were removed and the final flight samples installed.

The samples removed show (Figure VII-9a) far greater accumulations of particles than samples from the later orbital or ferry-flight phases of the mission (Figure VII-9b,c). Measured particle counts indicate particle distributions of $10^5/cm^2$ for the preflight exposed samples, as compared to $10^3/cm^2$ for the flight and ferry-flight samples. In all cases, the distribution of particle sizes is heavily concentrated in the size range < 10 μm diameter (similar to STS-1 POSA results). Additionally, the samples removed prior to flight show residue of water droplets from an inadvertent rain leak in the OPF on July 15, 1981. Yet, even these samples with visually dense particle accumulations indicate, as would be expected, little significant degradation in ultraviolet optical properties (Table VII-4). For comparison, results from preflight exposure at KSC for STS-1 are shown in Table VII-5.

The SEM analysis of the electrets indicates accumulations of chlorine, phosphorus, and silicon. Although other elements were detected, these three are most clearly of origin independent of the ferry flight.

The electrets were investigated before and after the flight with an X-ray microprobe scanning an area approximately 0.4 cm^2 for elemental abundances. For each detectable element, the postflight measured microprobe "counts" were subtracted from the preflight "counts". These values provide a means of estimating, at a glance, the relative increase in the measured abundance of a given element on the electrets after exposure. Table VII-6 is a summary of STS-2 electret results compared to STS-1 results. The variations from sample to sample are still under investigation.

An electret removed from the STS-2 preflight tray provided the results of Table VII-7, indicating the presence of some elements not seen on the flight electrets and greater relative abundances of all elements detected. The results of Table VII-7 may be compared to those of Table VII-6 simply by subtracting the pre-exposure counts from the post-exposure counts.

C. Summary

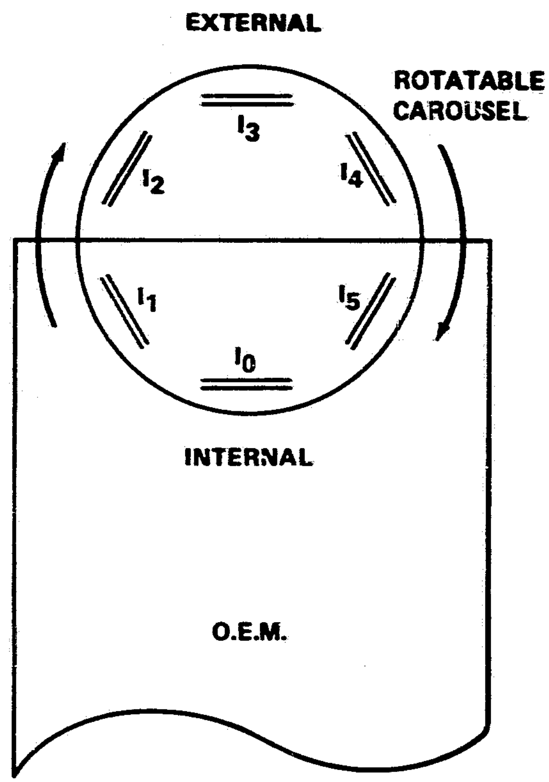
Several of the optical samples were investigated by the technique of Auger spectroscopy. Although the analysis of Auger data is incomplete at this time, there is not convincing evidence of even a monolayer-thick contaminant film. Trace quantities of carbon and oxygen were detected on all samples, including controls and samples of the ferry flight.

The analysis of results from the OEM and PSA is not yet complete. In summary, most of the data indicate the absence of a significant accumulation of contamination other than particulates on the optical samples. While the cause or mechanism of the in-flight degradation observed for OEM samples has not been established, the levels of change are small--considerably less than the levels of change (> 10%) associated with the accumulation of a single monolayer of a contaminant such as DC-704 pump oil, at a wavelength ≈ 2537 Angstroms. Most of the degradation of the samples of the passive arrays is probably due to the effects of adhering particles. Much of the particulate accumulation can be attributed to the Dryden/ferry-flight environments. Although the particle size distribution measurements are not complete at this time, preliminary results indicate sizes and numbers similar to those found on STS-1.

Following the completion of STS-2 preflight ground operations, the OPF at KSC was subjected to an intensive clean-up effort. Projected analyses of subsequent passive samples to be exposed at KSC should reflect the degree of success attained in this clean-up.

SAMPLE LISTING:

POSITION	MATERIAL
I_0	OPEN APERTURE
I_1	SAPPHIRE
I_2	LITHIUM FLUORIDE
I_3	CALCIUM FLUORIDE
I_4	MAGNESIUM FLUORIDE
I_5	QUARTZ



EVENT/LOCATION	TRANSMITTANCE				
	I_1	I_2	I_3	I_4	I_5
ORIGINAL VALUES/MSFC	.73	.86	.91	.89	.87
IECM/OEM FUNCTIONAL TEST/OPF/KSC	.72	.85	.91	.88	.87
*INITIAL ORBITAL VALUES	.72	.84	.91	.87	.87
FINAL ON–ORBIT VALUES	.70	.83	.91	.86	.86
FINAL VALUES/MSFC	.69	.80	.89	.86	.85
TOTAL CHANGE	–5.5%	–7.0%	–2.2%	–3.4%	–2.3%
CHANGE IN–FLIGHT	–2.8%	–1.2%	0	–1.2%	–1.2%
PREFLIGHT CHANGE (GROUND OPS)	–1.4%	–1.2%	0	–1.1%	0
ORIGINAL TO INITIAL ON–ORBIT CHANGE	–1.4%	–2.3%	0	–2.3%	0
FINAL ON–ORBIT TO FINAL LAB VALUES CHANGE	–1.4%	–3.6%	–2.2%	0	–1.2%

* CORRECTED VALUES, SUBJECT TO POSSIBLE REVISION PENDING SYSTEMATIC ANALYSIS OF INSTRUMENT FLIGHT PERFORMANCE. IN–FLIGHT PERCENTAGE CHANGE NOT SUBJECT TO REVISION.

Figure VII-1. Optical Effects Module: summary results STS-2.

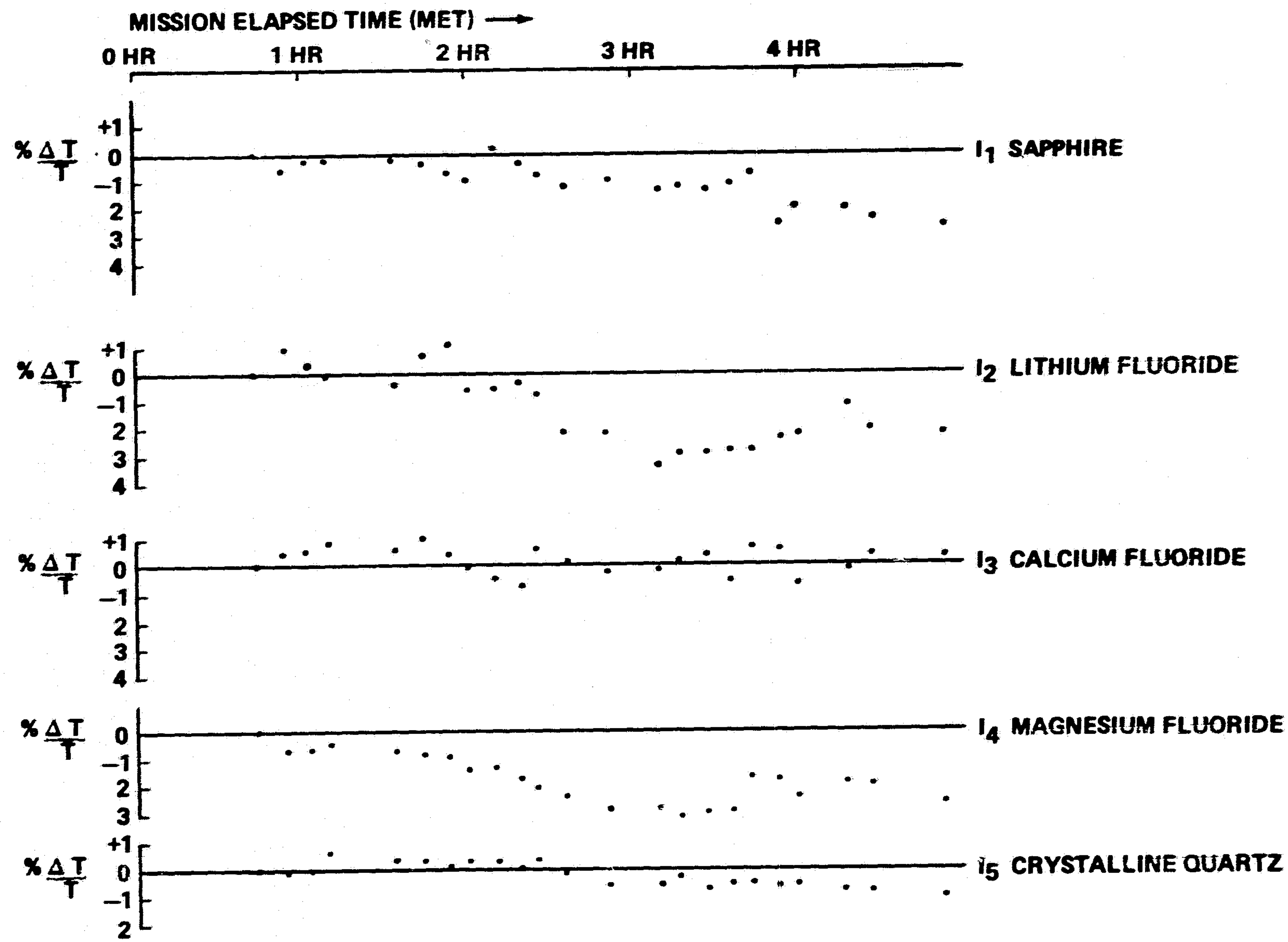


Figure VII-2. Optical Effects Module: STS-2 early orbital data.

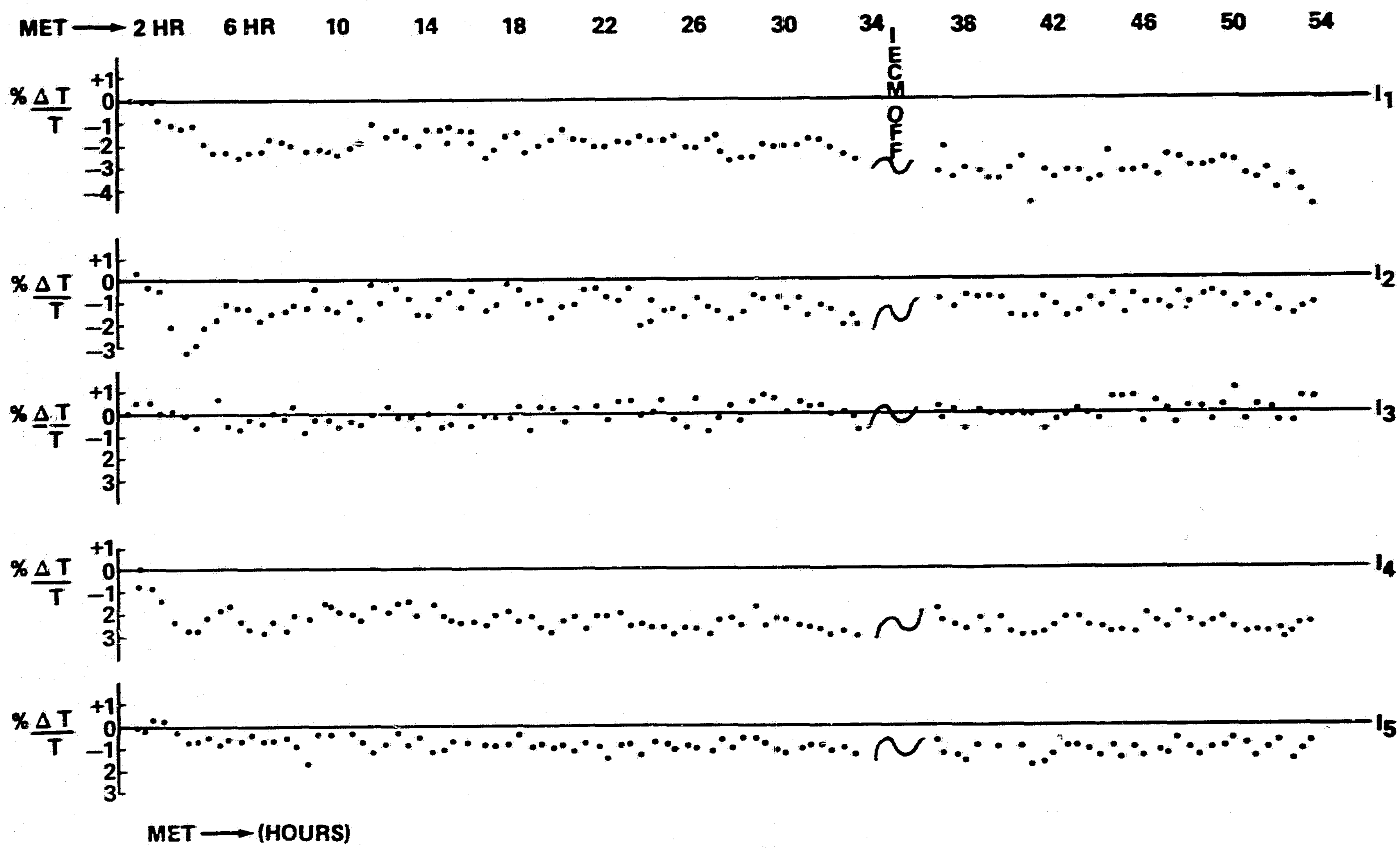


Figure VII-3. Optical Effects Module: percent change in transmittance — total mission summary.

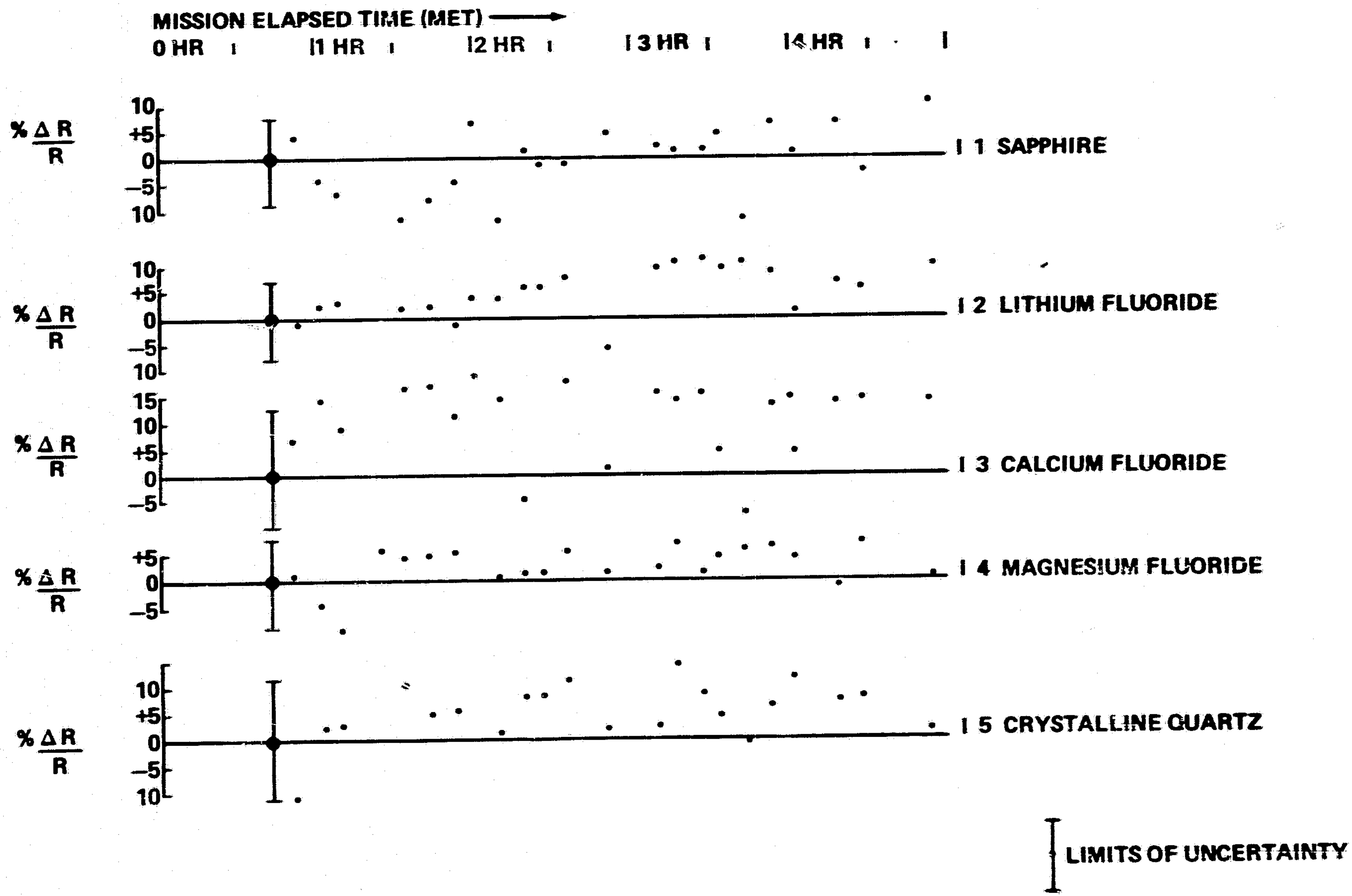


Figure VII-4. Optical Effects Module: scatter data — STS-2 early orbital.

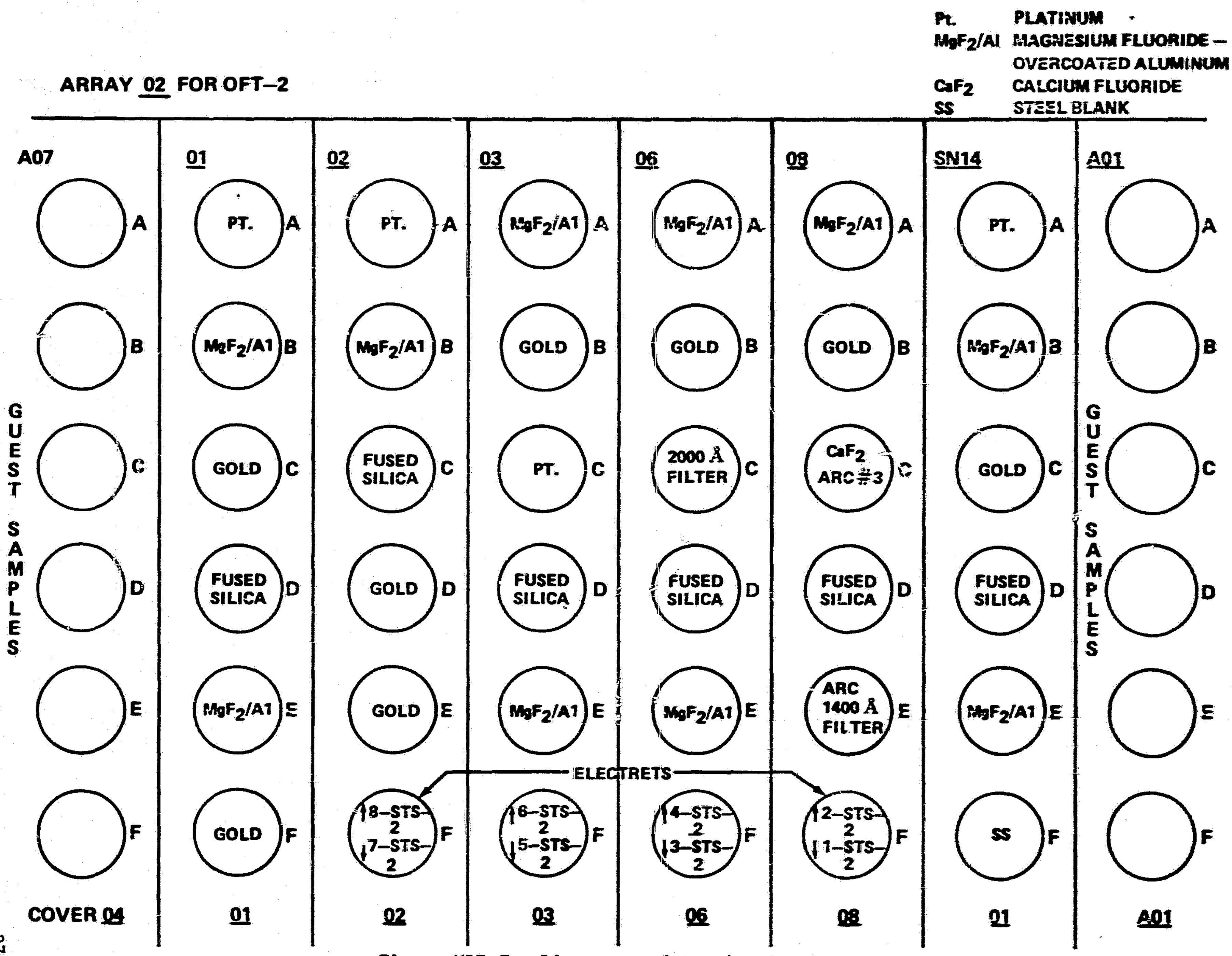


Figure VII-5. Directory of Passive Sample Array.

TABLE VII-1. PASSIVE SAMPLE ARRAY OPTICAL PROPERTIES: VACUUM ULTRAVIOLET REFLECTING OPTICS

Sample	Wavelength λ(nm)	Range of ΔR (±0.01 uncertainty)	Average % Change
MgF_2/Al (8 samples)	120	-0.07 to 0	-1.5
	160	-0.01 to +0.04	-1.3
	200	-0.03 to +0.01	-1.4
	240	-0.04 to -0.01	-0.6
	280	-0.06 to -0.01	-1.6
Gold (6 samples)	120	-0.03 to 0	-4.4
	160	-0.01 to +0.01	0
	200	-0.01 to +0.01	0
	240	-0.02 to +0.01	0
	280	-0.03 to 0	0
Platinum (4 samples)	120	0 to +0.01	0
	160	0 to +0.03	0
	200	-0.01 to +0.02	0
	240	-0.03 to -0.01	-2.9
	280	-0.02 to 0	0

TABLE VII-2. PASSIVE SAMPLE ARRAY OPTICAL PROPERTIES: VACUUM ULTRAVIOLET TRANSMITTING OPTICS

Sample	λ(nm)	ΔT [a]	% Change Transmittance
1400 Å Filter (1 sample)	120	-0.01	0
	130	-0.01	0
	140	0	0
	150	-0.01	0
	160	0	0
2000 Å Filter (1 sample)	175	+0.005	0
	185	+0.01	0
	200	-0.005	0
	210	-0.005	0
	220	0	0
Calcium Fluoride (CaF_2) (1 sample)	120	-0.01	0
	150	0	0
	200	-0.02	-0.022
	240	-0.01	0
	280	+0.01	0
Fused Silica (6 samples)	160	0 to +0.01	0
	180	-0.02 to +0.02	-2.2
	200	-0.01 to +0.04	-1.2
	240	-0.04 to +0.03	-1.0
	280	-0.01 to +0.01	0

a. Measurement uncertainty: $\Delta T_u = \pm 0.01$

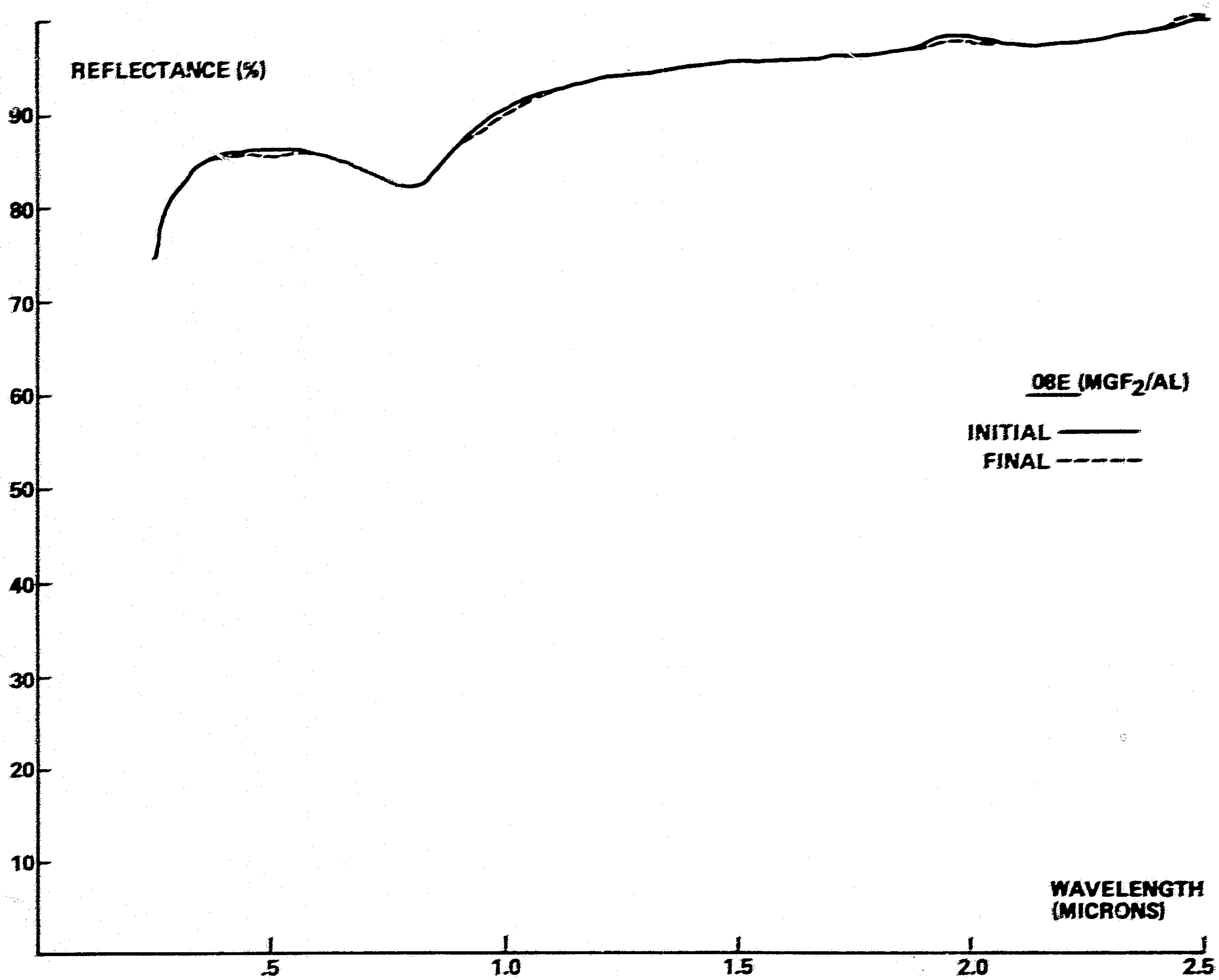


Figure VII-6. Diffuse reflectance of sample from PSA — STS-2 orbital.

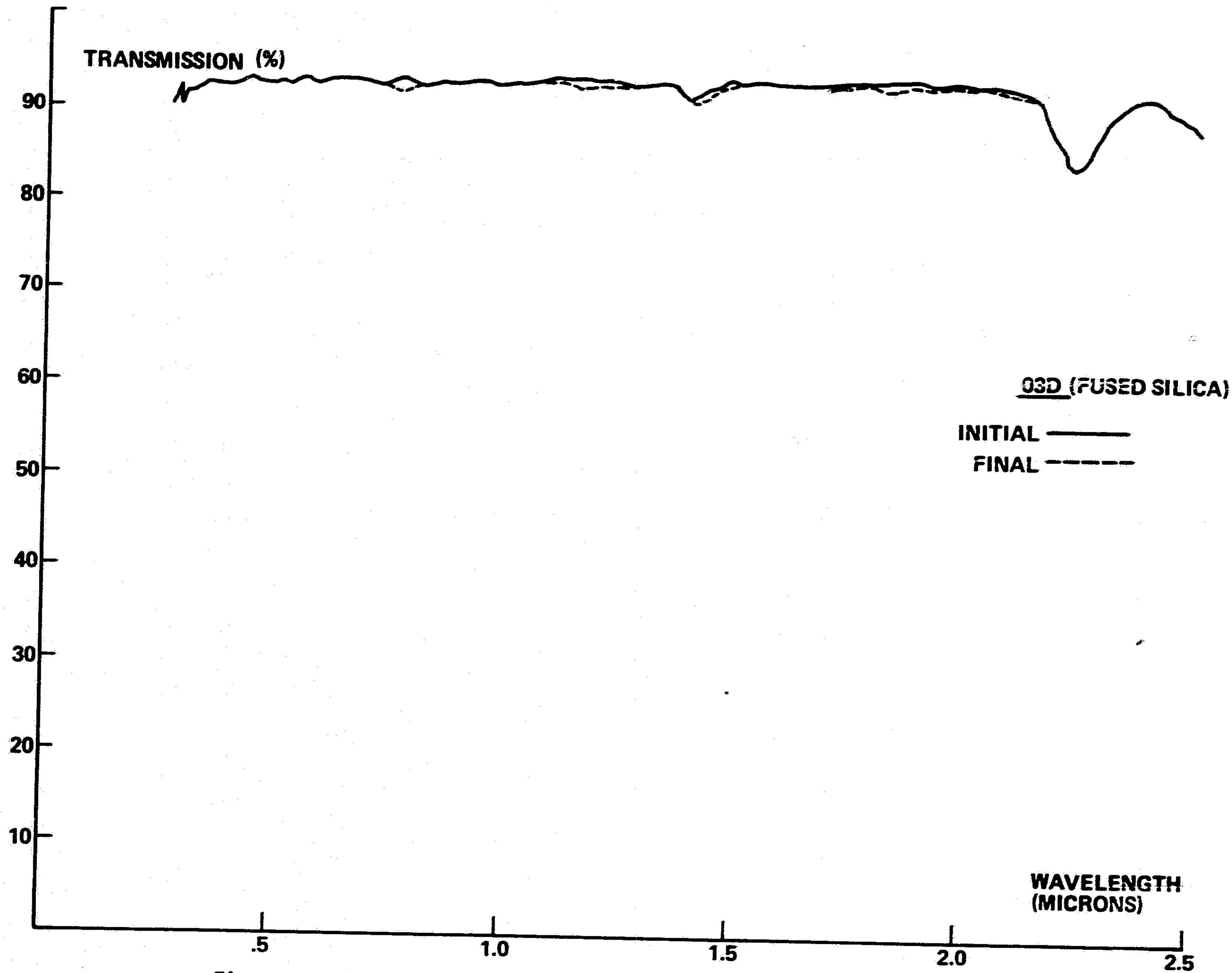


Figure VII-7. Transmittance of sample from PSA — STS-2 orbital.

TABLE VII-3. POSA/FERRY FLIGHT OPTICAL PROPERTIES: VACUUM ULTRAVIOLET

Sample	λ(nm)	Range of ΔR (±0.01 uncertainty)	Average % Change
MgF_2/Al (2 samples)	120	-0.02 to -0.03	-3.5
	160	0 to -0.01	0
	200	-0.02 to -0.04	-2.8
	240	-0.02 to -0.04	-1.5
	280	-0.04 to -0.05	-1.3
Gold (2 samples)	120	-0.02	-7.1
	160	-0.01	0
	200	0 to -0.02	-2.5
	240	-0.02	-3.7
	280	-0.02	-5.9
Pyrex (1 sample)	120	-0.01	0
	160	0	0
	200	0	0
	240	0	0
	280	0	0

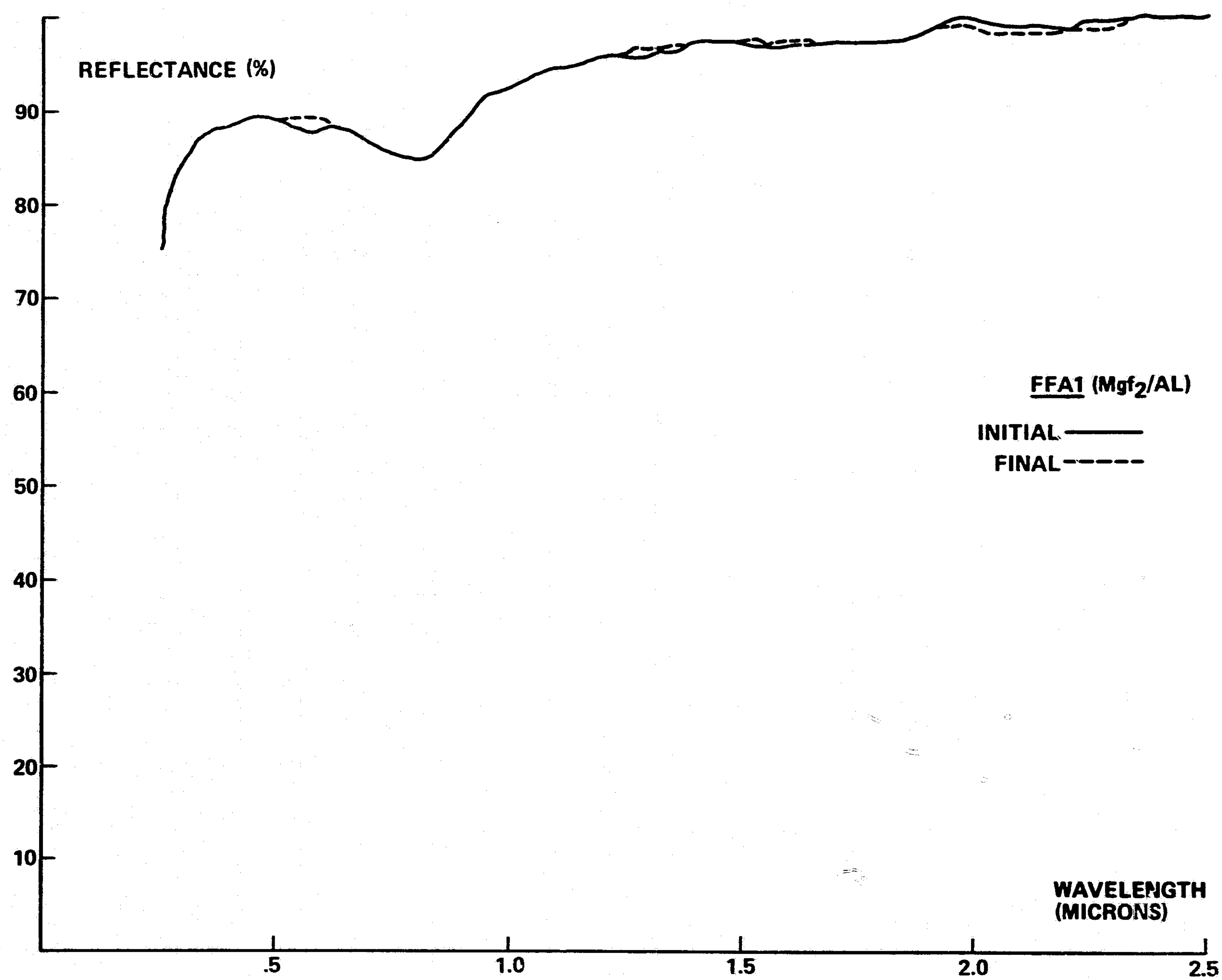
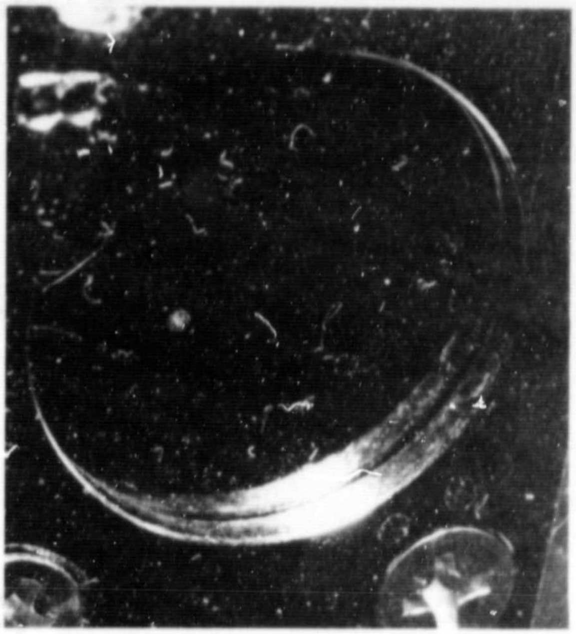
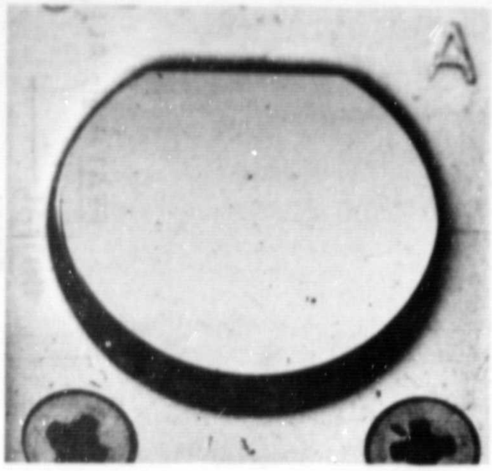


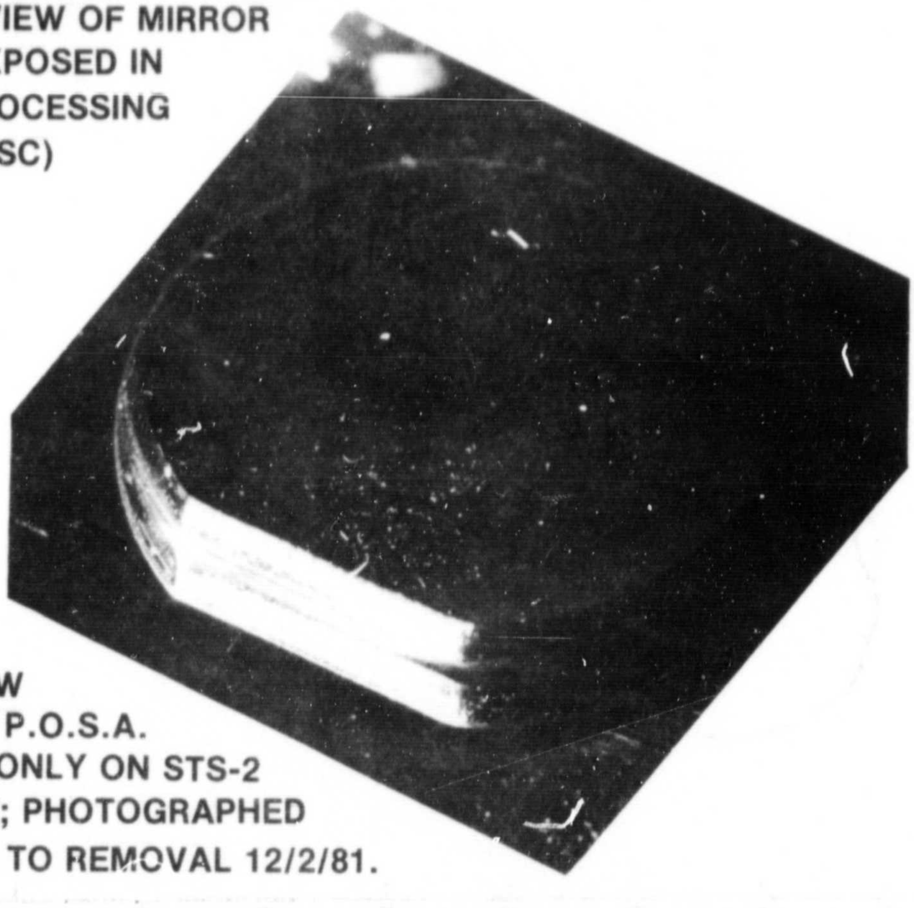
Figure VII-8. Diffuse reflectance of sample from POSA/ferry flight — STS-2.



(A) CLOSE-UP VIEW OF MIRROR IN P.S.A. EXPOSED IN ORBITER PROCESSING FACILITY (KSC)



(B) POST-FLIGHT CLOSE-UP VIEW OF P.S.A./STS-2 ORBITAL UNIT



(C) CLOSE-UP VIEW OF MIRROR IN P.O.S.A. TRAY FLOWN ONLY ON STS-2 FERRY-FLIGHT; PHOTOGRAPHED AT KSC PRIOR TO REMOVAL 12/2/81.

Figure VII-9. Close-up views of PSA mirrors.

TABLE VII-4. STS-2 DATA ANALYSIS
VACUUM UV RESULTS FOR EXPOSED PSA TRAY #07
PREFLIGHT (KSC) EXPOSURE

Wavelength (Angstroms)	% Δ (Platinum)	% Δ (Gold)	% Δ (MgF_2/Al)
1250	*	*	-3.6
1400	*	*	-5.6
1600	*	*	*
1800	*	*	*
2000	*	*	*
2200	*	*	*
2400	*	*	*
2600	*	*	-3.3
2800	*	*	*

$$\% \Delta = \frac{R_o - R}{R_o} \times 100, \text{ where } R_o = \text{original reflectance}$$

R = reflectance after exposure

* Percent change in reflectance $\leq$ 2%, limit of measurement uncertainty

TABLE VII-5. STS-1 DATA ANALYSIS
VACUUM UV RESULTS FOR EXPOSED PSA TRAY #012
PREFLIGHT (KSC) EXPOSURE

Wavelength (Angstroms)	$\% \Delta_T$ (Fused Silica)	$\% \Delta_R$ (Gold)	$\% \Delta_R$ (MgF_2/Al)
1250	*	*	-3
1400	*	*	*
1600	*	-5.6	*
1800	-6.7	-5.3	-1.5
2000	-2.8	*	-2.8
2200	*	*	-2.7
2400	*	*	-3.8
2600	*	-4.0	-6.3
2800	*	*	-4.9

* Percent change in reflectance or transmittance $\leq$ 2%

$$\% \Delta_R = \frac{R_o - R}{R_o} \times 100,$$ where R_o = original reflectance
R = reflectance after exposure

$$\% \Delta_T = \frac{T_o - T}{T_o} \times 100,$$ where T_o = original transmittance
T = transmittance after exposure

TABLE VII-6. ELECTRET RESULTS

ELEMENT	ELECTRET ORIENTATION (SHUTTLE Z-AXIS)	RELATIVE ELEMENTAL ABUNDANCE INCREASE *			
		STS-2 TOTAL MISSION (8 Electrets)	STS-1 TOTAL MISSION (3 Electrets)	STS-2 FERRY FLIGHT (2 Electrets)	STS-1 FERRY FLIGHT (2 Electrets)
Chlorine	up (-Z)	220, 66, 250, 300	0	0	0
	down (+Z)	53, 86, 130, 300	2, 0	0	0
Silicon	up (-Z)	1210, 764, 724, 1060	509	499	0
	down (+Z)	0, 469, 700, 450	9, 1	160	0
Potassium	up (-Z)	0, 100, 75, 0	0	0	0
	down (+Z)	0, 0, 0, 0	0, 65	60	0
Calcium	up (-Z)	100, 100, 50, 100	0	50	0
	down (+Z)	0, 125, 140, 50	3520, 0	130	450
Aluminum	up (-Z)	186, 0, 0, 0	5520	774	1577
	down (+Z)	0, 0, 0, 0	0, 0	1488	4842
Copper	up (-Z)	30, 30, 45, 40	0	30	0
	down (+Z)	30, 30, 140, 40	0	30	0
Phosphorus	up (-Z)	0, 70, 100, 70	0	0	0
	down (+Z)	0, 100, 150, 125	0, 0	0	0
Sulphur	up (-Z)	250, 100, 125, 50	210	0	0
	down (+Z)	0, 0, 0, 175	200, 0	800	0
Chromium	up (-Z)	60, 100, 80, 70	0	60	0
	down (+Z)	50, 125, 50, 50	0, 0	120	0

* X-Ray microprobe proportional counts per element

TABLE VII-7. ELECTRET MICROPROBE ANALYSIS
PREFLIGHT EXPOSURE AT KSC

Element	Post-KSC Exposure (counts)	Pre-KSC Exposure (counts)
Cl	1,000	400
Si	5,000	800
K	500	-
Ca	750	-
Al	19,000	17,500
Cu	50	-
P	100	-
S	1,000	-
Cr	500	-
Na	1,000	-
Mg	1,000	-
Fe	750	Trace
Ni	100	-

- Indicates no pre-KSC exposure counts measured

VIII. TEMPERATURE-CONTROLLED QUARTZ CRYSTAL MICROBALANCE AND CRYOGENIC QUARTZ CRYSTAL MICROBALANCE

J. A. Fountain

A. Temperature-Controlled Quartz Crystal Microbalance

The purpose of the Temperature-Controlled Quartz Crystal Microbalance (TQCM) system is to measure condensible molecular flux in the payload bay of the Space Shuttle [1]. Five quartz crystal microbalance sensors are located in the IECM so that they measure molecular adsorption in each of the Orbiter axes, +X, -X, +Y, -Y, and +Z. The temperature of each sensor is controlled by a thermoelectric device so that contamination can be measured as a function of four preset temperatures: +30°C, 0°C, -30°C, and -60°C. The command sequence is the following: during ascent and descent the sensors are not controlled and are allowed to seek ambient temperature. This is a battery power conservation measure. When orbital altitude is reached, the TQCM sensors begin their orbital measuring cycle routine (Figure VIII-1). The sensors are commanded to 80°C for 30 min, which is used as an initial clean-up. They are then stepped through a program of 2-hr collection periods at each temperature with a 30-min, 80°C period between each collection period. The collection periods go in descending order from +30°C to -60°C. At the end of the 2 hr at -60°C, the temperature is stepped up in 30-min periods. Then the cycle is started again. The cycle takes 11.5 hr to complete; since the STS-2 orbital phase lasted approximately 53 hr, the TQCM system completed four cycles and was into the fifth when the mission was terminated.

In summary, the TQCM measures the mass per square centimeter of the condensible molecular flux in the cargo bay as a function of temperature, direction, and time.

B. STS-2 Measurements--TQCM

A Faraday Laboratories, Inc., TQCM system was flown on STS-2. It consisted of a controller (serial number A-2) and five sensor heads with the following serial numbers:

Orbiter Axis	TQCM Sensor Serial Number
+X	S2H2E6
-Y	S5H5E5
+Y	S7H7E7
-Z	S8H8E8
-X	S9H9E9

The outputs of these sensors are (1) a frequency which is proportional to mass adsorption per unit area at a sensitivity of 1.56×10^{-9} $g/cm^2/Hz$ and (2) the temperature of the sensor in degrees Celsius.

The output frequency of a TQCM sensor is affected by many factors, and the resultant curve must be evaluated carefully in terms of sensor characteristics and source characteristics. Some of the main sensor characteristics which must be accounted for are: (1) sensor crystal temperatures (both sensing and reference crystals); (2) sensor orientation, direction, and distance from sources; (3) effects of sudden changes of the radiative energy environment on the crystals from the Sun or from the Earth albedo; and (4) effects of pressure changes (this is mainly a matter of water release and absorption by the magnesium fluoride coating on the crystals during ascent and descent, respectively. The sources are evaluated in terms of their (1) nature -- whether engine firings, water or other dumps, material outgassing, offgassing, etc., (2) source temperatures -- due to intrinsic heat generation and to solar and Earth albedo input, and (3) direction and distance.

The frequency output curve from the +X axis sensor is shown for each of the command cycles in Figures VIII-2 through VIII-6. It is plotted for the entire orbital phase as a function of mission elapsed time (MET). Curves for the other sensors will not be presented in this preliminary report, but a summary of the performance of all the sensors will be presented. Unfortunately, the sensor facing in the -Z axis operated intermittently. Although some data were obtained from it, it will not be presented unless further laboratory testing allows evaluation of the cause of its intermittent operation and a reliability factor can be assigned to its data. Initial inspection shows that the sensor, which is the upward pointing sensor when the Shuttle is horizontal on the ground, has evidence of heavy particulate and fibrous contamination.

Several of the features of the +X curve will be discussed. The first command is for the sensors to heat to +80°C for the initial desorption of contaminants which might be present from the prelaunch and launch environment. This command is given when the on-orbit signal is received from the Shuttle and occurs at 37 min MET. The first collection measurement command is given at 1 hr 7 min. When the TQCM sensor is given a command to seek a temperature lower than 80°C, there ensues a brief period in which two changes take place. First, the crystal temperatures rapidly descend to the commanded temperature. As a result of these temperature transits, the frequency varies due to the effects of the temperature-frequency characteristics of the crystals. This is usually seen as a decrease in the frequency level, such as is seen at 1 hr 7 min in Figure VIII-2 and after each ensuing +80°C setting. After a period of approximately 3 to 12 min, depending on the magnitude of the temperature change, the crystals reach the commanded temperature and begin to control at that temperature. The frequency-temperature effects have settled out, and, if a molecular flux is present, it begins to collect on the crystal surface. This causes a frequency increase, and this rate of increase provides the desired data: mass adsorbed, per unit area, per unit time. The rate of collection may be perturbed by any of the effects mentioned in the preceding paragraph. One of the most pronounced effects, as seen in Figures VIII-2 through VIII-6, occurs when

the Shuttle comes out of the Earth's shadow and then crosses the night-day terminator. This effect can be seen, for instance, at 7 hr. A sharp drop in frequency is observed when the sensor exits from the Earth's shadow at 7 hr 2 min. This causes a momentary imbalance between the sensor crystal and the reference crystal. The thermoelectric temperature control device begins to correct the imbalance. However, in another 7 to 8 min the Shuttle crosses the night-to-day terminator line on the Earth. The sensor surface receives another abrupt change in its radiative flux, and the correction process begins again. This results in the doublet signature which is seen in the frequency profile throughout the mission. The effect is less when this sensor enters the Earth's shadow. This effect is different on the other sensors depending on which side of the IECM is facing the Sun when the Shuttle enters and exits the shadow. Because of the shape of the temperature-frequency characteristic curve, the effect is more pronounced at -60°C and is least at +30°C. This phenomenon represents a disturbance in the adsorption rate measurement, the effects of which need to be more thoroughly understood.

A single feature which should be discussed is the large frequency increase which occurs midway in the first 30°C setting and peaks at 2 hr 18 min. Several things are happening during this period. This is the period of payload bay door openings and closings. The Shuttle is also entering the Earth's shadow, and there may also be continued effects due to the pressure change from launch to orbital altitude. Therefore, since this is such an active period, it is recommended that the apparent rapid rise in contamination and the succeeding rapid decrease be viewed with reservation until the events during this time period have been further defined.

Total adsorption determinations were made for each of the sensors at each of the collection temperatures. Values were read at the onset of adsorption and subtracted from the maximum value during that period to obtain the change. These values were summed for the four sensors and an average value obtained. All of these values are summarized in Table VIII-1, and the averages are plotted in Figure VIII-7 to show the overall trends as the mission progressed. This figure shows: (1) With the exception of the first point at +30°C, which has been discussed previously as being still under investigation, there appears to be little difference between the adsorption at +30°C and 0°C, and then a slight increase at the -30°C and -60°C settings. (2) For each temperature as the cycles progress into the mission, the rate of adsorption generally decreases.

C. Postflight Laboratory Test--TQCM

In order to give a general indication of the relative operation of the TQCM system in a more familiar environment, a postflight laboratory test was made on the TQCM. The vacuum system used was a mechanically roughed, oil diffusion system with a liquid nitrogen trap on the main pump orifice. Vacuum pressure was measured with a Vacuum Industries ionization gauge. The TQCM sensors were mounted on an aluminum plate so that all faced in the same direction. The commands were given in the

same sequence as on STS-2. The frequency increased in a fairly linear manner over the 2-hr period. Four sensors (+X, -X, -Y and +Y) adsorbed a total of 7407 Hz (11,555 ng cm^{-2}) for an average of 1852 Hz (2889 ng cm^{-2}). Figure VIII-8 shows a plot of the average values for the four TQCM sensors at -60°C over the same collection period as on STS-2. Caution should be used, however, in using this comparison. A diffusion pumped vacuum system presents an environment quite different from that of the Shuttle. Therefore, it should not be considered conclusive but only as a general indicator of the difference in molecular adsorption between the STS-2 mission and a laboratory vacuum system at a vacuum level of 7 x 10^{-6} torr.

D. Cryogenic Quartz Crystal Microbalance

The Cryogenic Quartz Crystal Microbalance (CQCM) represents a special use of the quartz crystal microbalance sensor in that it has no temperature control, but is designed to radiatively cool itself to cryogenic temperatures when it points into deep space for long periods of time. It is specifically designed to measure water vapor on a mission with a long cold soak (STS-3). (For a full description, see Reference 1.) However, because it requires so little power (40 mW), it is flown as a part of the regular complement of experiments on the IECM with the recognition that its full potential is not realized. What it provides on a flight such as STS-2 is a cumulative record of mass adsorption at temperatures which are always at least slightly below ambient. It also provides data for evaluation of its passive thermal radiator system.

The CQCM sensors, $-Z_1$ and $-Z_2$, operated throughout the STS-2 mission. A tabular summary of the data for each phase is given in Table VIII-2. Since a stable temperature was never achieved, it is difficult to separate temperature-frequency effects from adsorbed mass. Therefore, for purposes of this report, frequency changes are given but are not converted into mass adsorbed. This is being further analyzed in the laboratory.

E. Conclusions

This preliminary report gives an overall view of the TQCM and CQCM measurements on STS-2. The data analysis from these systems is far from complete; indeed, it has just begun. Plots of the -X, +Y, and -Y axes for TQCM measurements will be published, and molecular adsorption will be investigated in terms of rates for specific times, in addition to total and average values. The -Z sensor will be tested, and an attempt will be made to salvage some measurements. Time periods of unusual activity will be studied in detail and correlated with events and Shuttle orientation.

Quantitative mass adsorption values for the CQCM cannot be given at this time. Further laboratory testing of the instrument is needed to determine how much of the frequency change given in Table VIII-2 is due to contamination and how much is due to frequency-temperature effects. A major success of the CQCM on STS-2 was the operation of its passive thermal radiator system. This system was able to cool an operating quartz crystal microbalance sensor to -52.11°C for a short time without using any power.

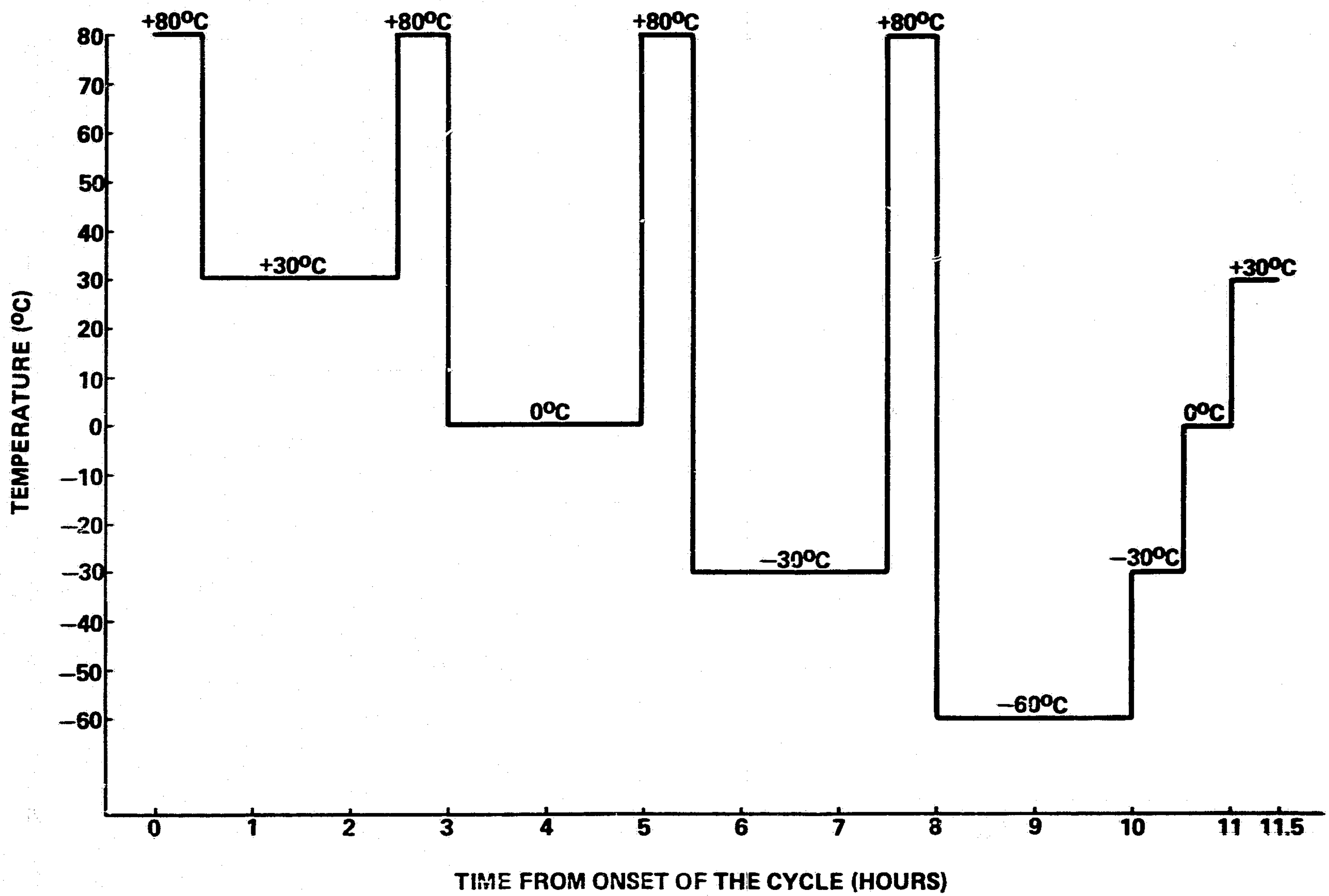


Figure VIII-1. TQCM orbital-phase command sequence.

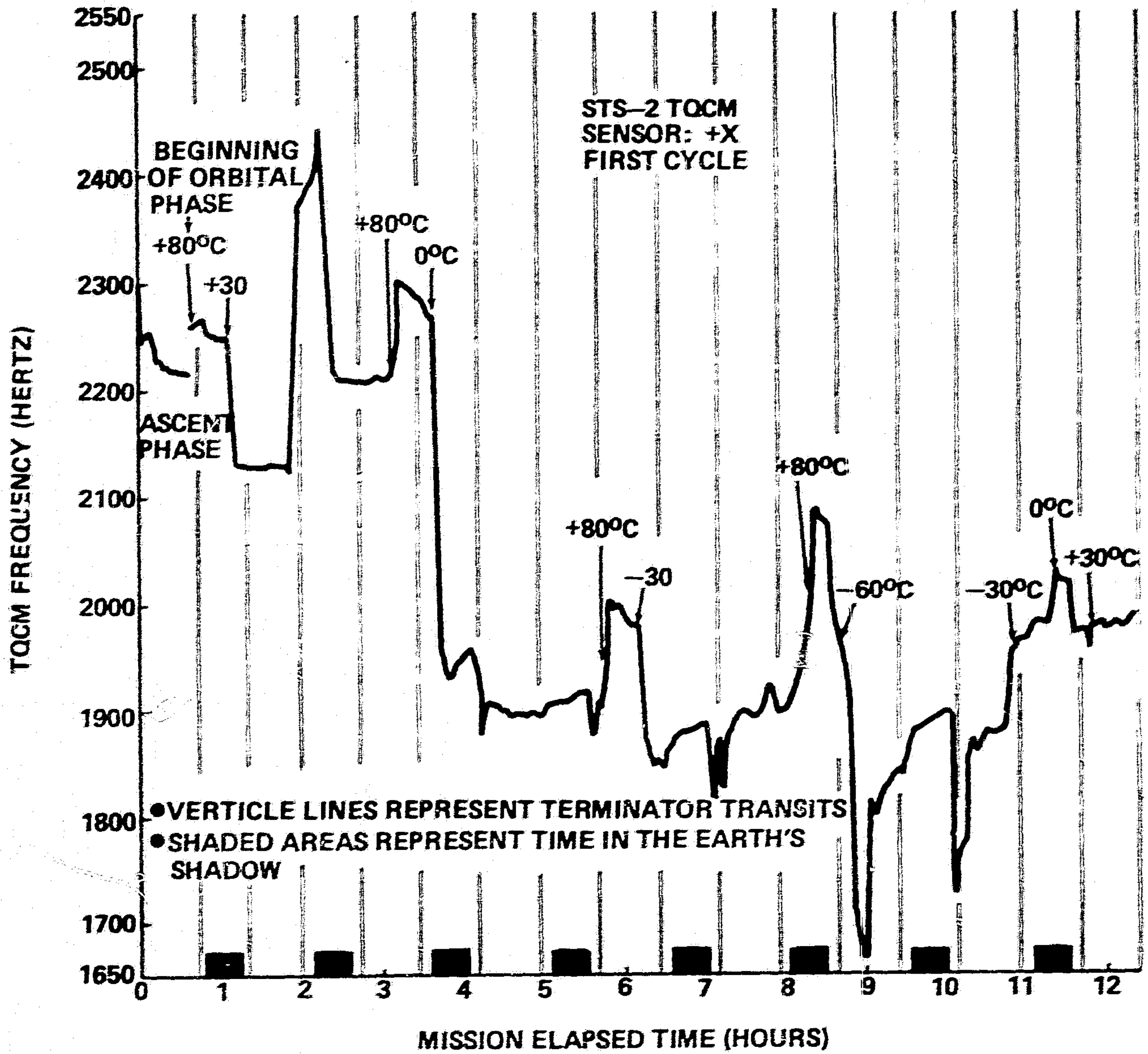


Figure VIII-2. STS-2, TQCM, sensor: +X, first cycle.

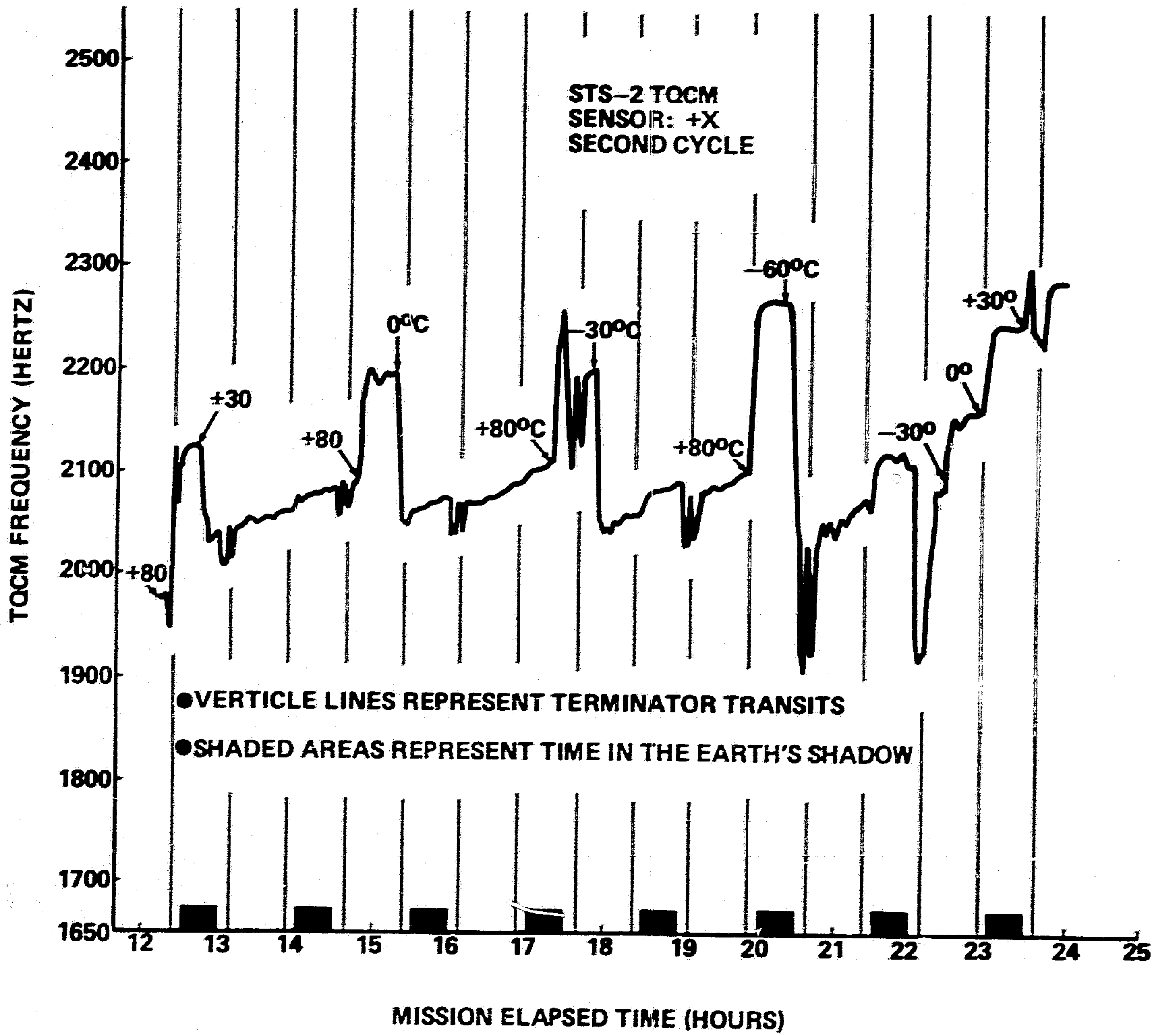


Figure VIII-3. STS-2, TQCM, sensor: +X, second cycle.

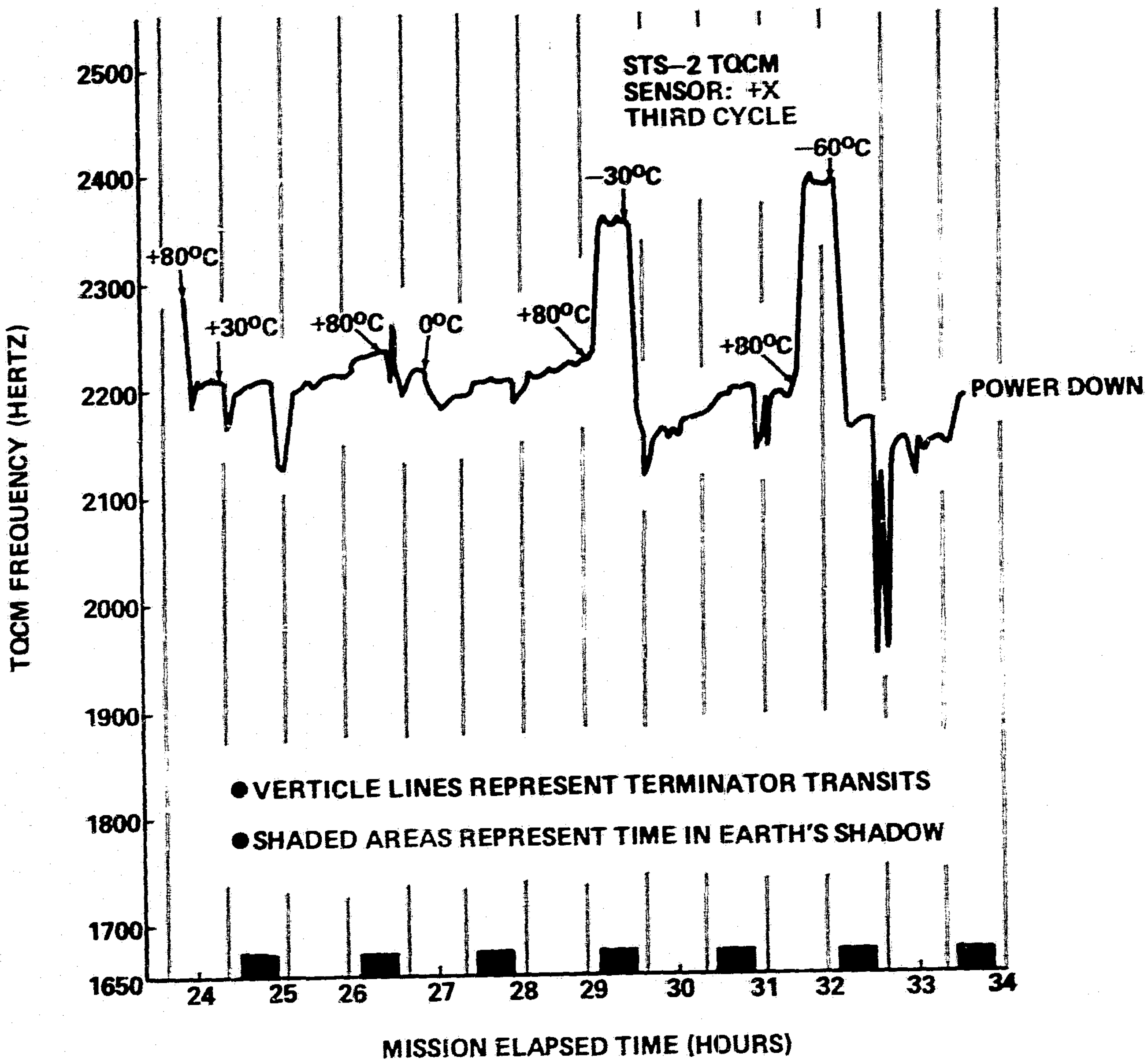


Figure VIII-4. STS-2, TQCM, sensor: +X, third cycle.

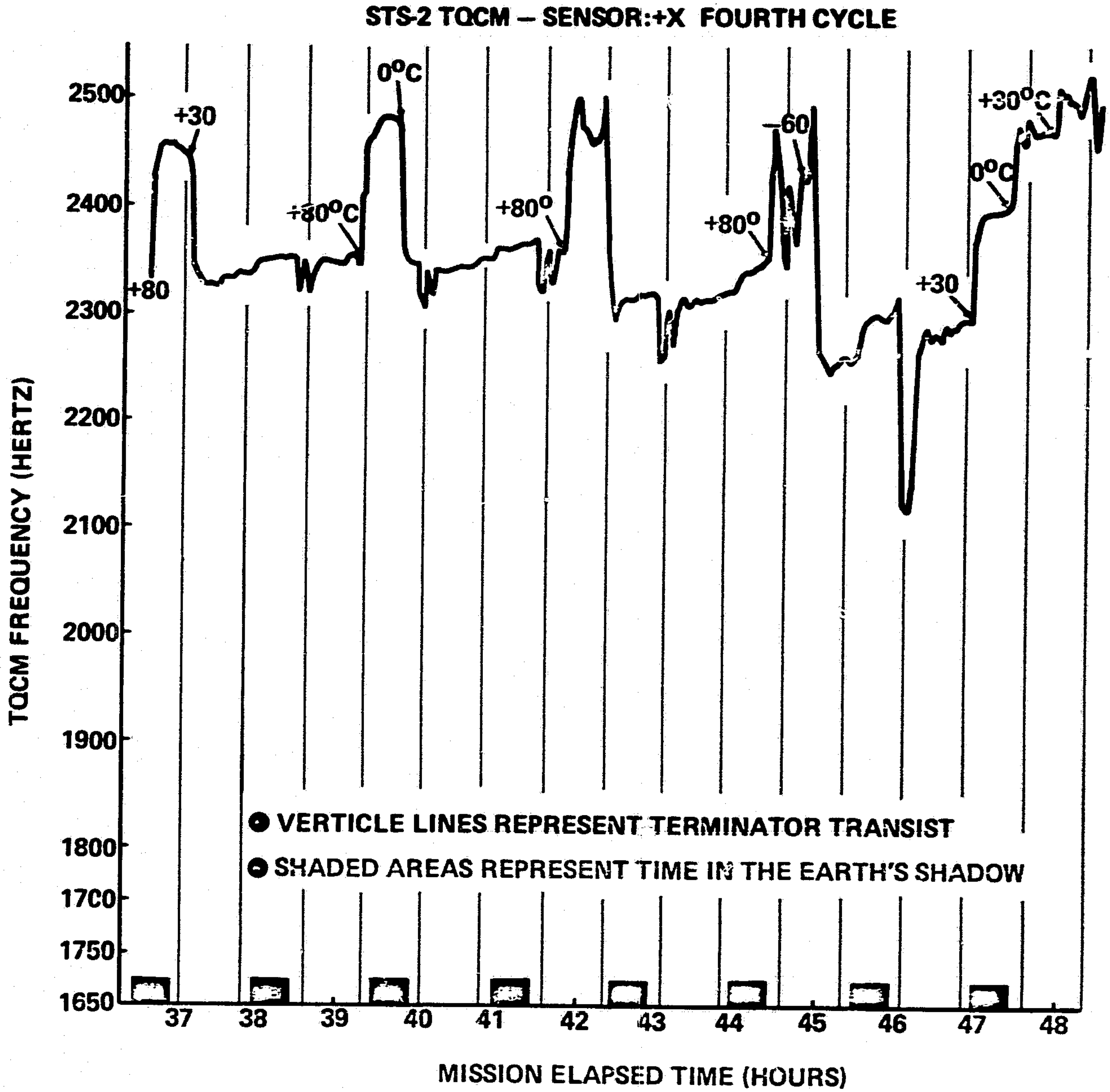


Figure VIII-5. STS-2, TQCM, sensor: +X, fourth cycle.

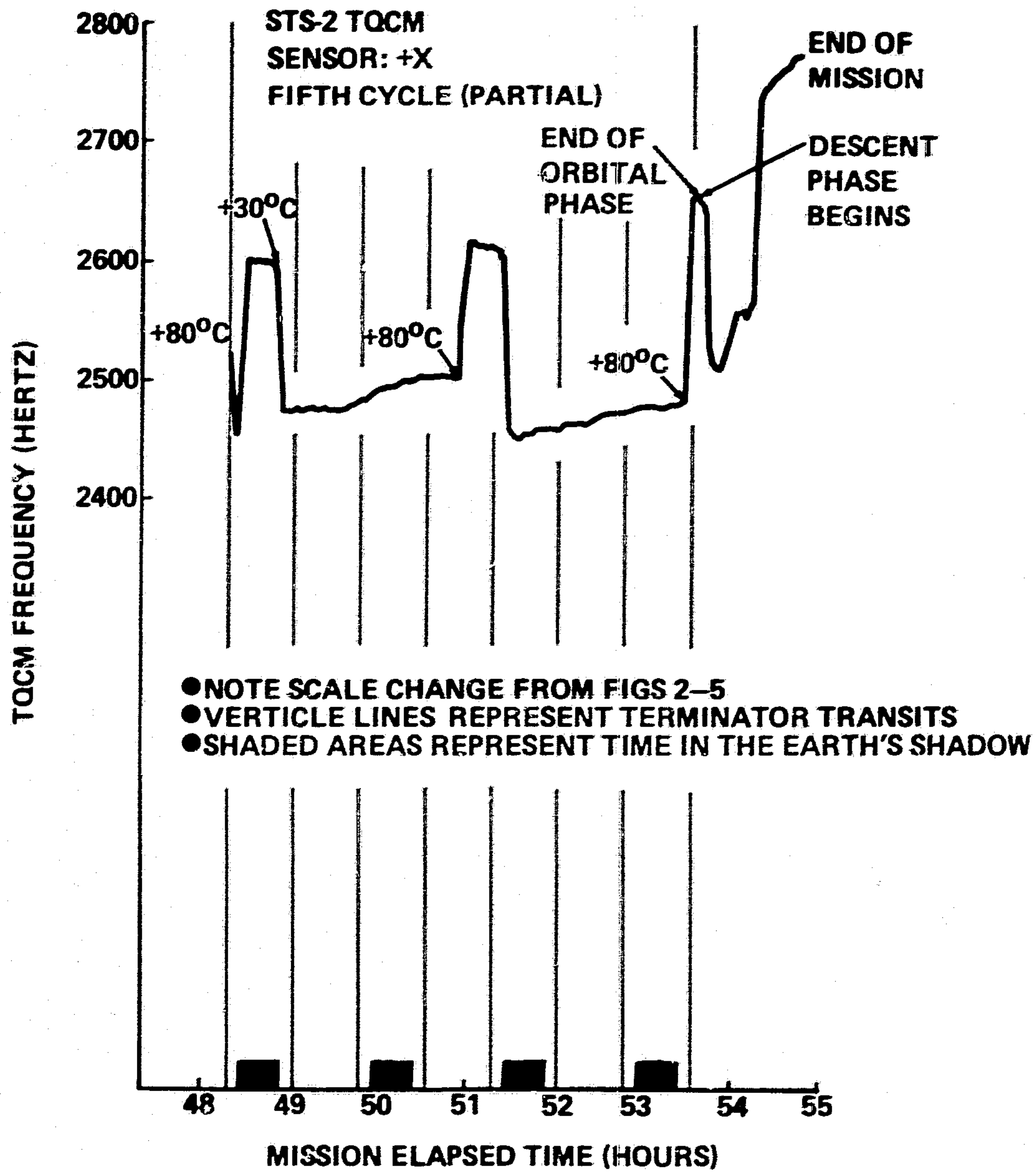


Figure VIII-6. STS-2, TQCM, sensor: +X, fifth cycle and descent.

TABLE VIII-1. SUMMARY OF THE ADSORBED CONTAMINATION FOR EACH SENSOR DURING ORBITAL PHASE

	+30°C						0°C						-30°C						-60°C					
Cycle	-X	+X	+Y	-Y	Total	Avg.	-X	+X	+Y	-Y	Total	Avg.	-X	+X	+Y	-Y	Total	Avg.	-X	+X	+Y	-Y	Total	Avg.
1	198	500	251	245	1193	298	33	41	58	112	243	61	176	139	83	181	579	145	64	360	479	285	1189	298
2	37	128	53	136	354	89	92	94	36	55	276	69	45	92	61	33	231	58	85	334	306	106	831	207
3	70	119	33	123	345	86	86	72	39	67	264	66	41	131	50	62	284	72	33	44	228	134	438	109
4	11	42	23	158	234	59	75	103	27	81	285	72	108	81	34	62	285	72	73	120	273	14	480	120
5	19	47	87	16	168	42	84	50	19	3	156	39												

Values are in nanograms cm^{-2}.

The measurement period of each value is 2 hours.

Beginning times of the cycles:
1 - 0 h 41 m
2 - 12 h 15 m
3 - 23 h 53 m
4 - 36 h 43 m
5 - 48 h 20 m

● SENSOR TEMPERATURES: +30°C, 0°C, −30°C, −60°C

● DATA POINTS REPRESENT THE AVERAGE VALUES OF THE +X, −X, +Y AND −Y SENSORS FROM TABLE II.

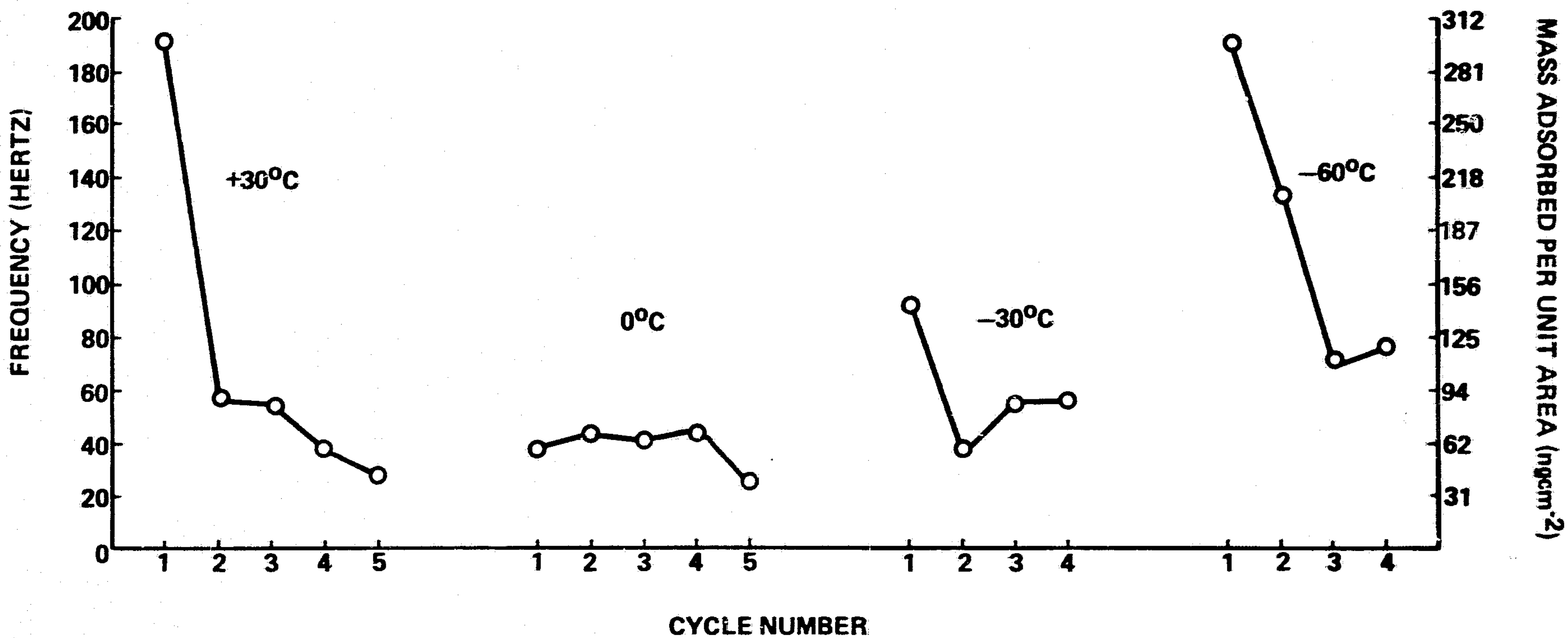


Figure VIII-7. Summary of STS-2 TQCM average values.

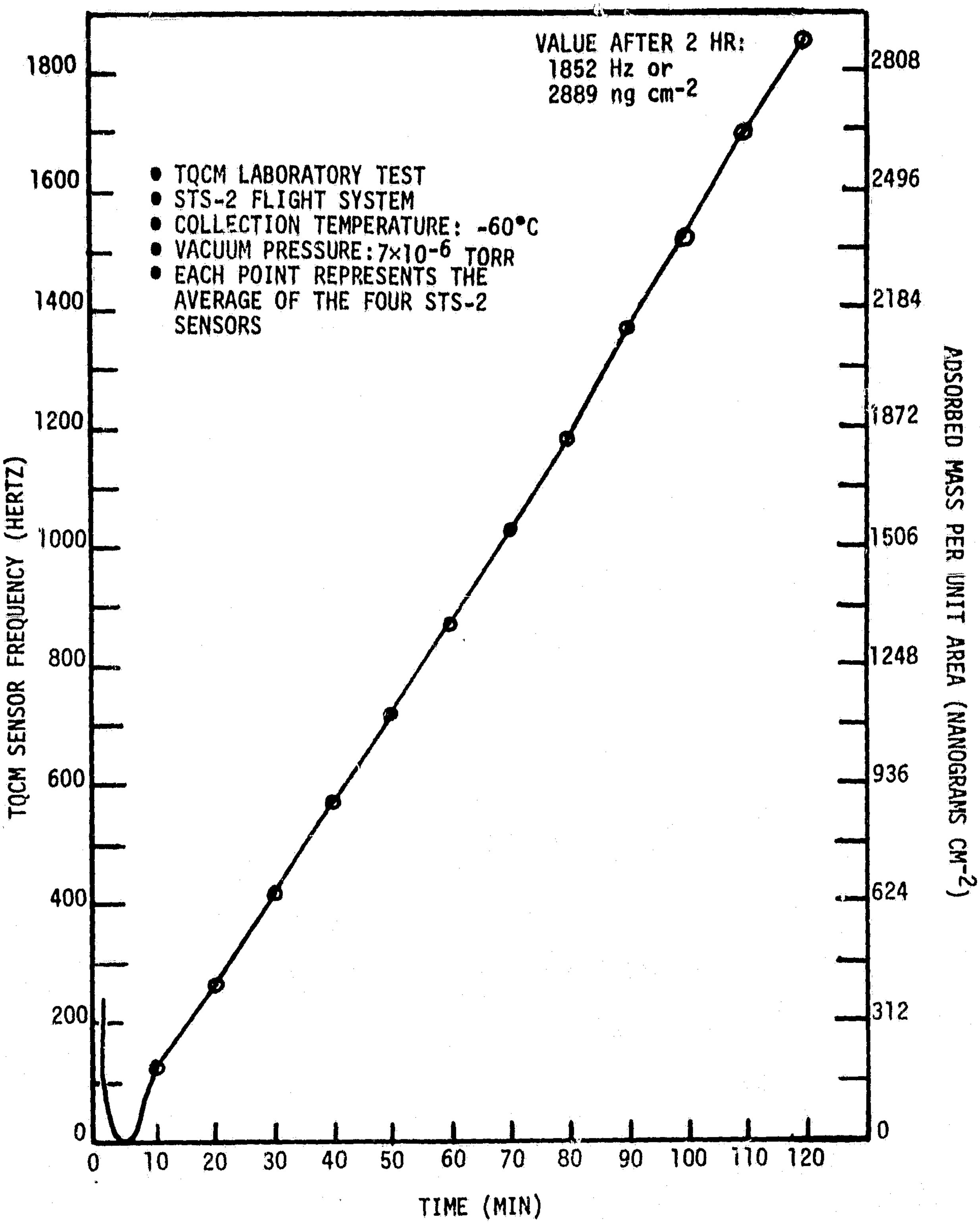


Figure VIII-8. Laboratory test of STS-2 TQCM system.

TABLE VIII-2. CQCM FREQUENCY AND TEMPERATURE EXTREMES BY PHASE

	Ascent Phase		Orbital Phase		Descent Phase	
	Sensor $-Z_1$	Sensor $-Z_2$	Sensor $-Z_1$	Sensor $-Z_2$	Sensor $-Z_1$	Sensor $-Z_2$
Beginning Frequency (Hz)	1422	1425	1481	1420	1262	981
Maximum Frequency (Hz)	1481	1511	1506	1420	1332	1244
Minimum Frequency (Hz)	1396	1421	1072	782	1225	913
Change in Frequency (Hz)	85	90	434	638	107	331
Final Frequency (Hz)	1481	1421	1263	981	1313	1053
Beginning Temperature (°C)	22.61	22.61	20.70	19.75	4.49	4.49
Maximum Temperature (°C)	23.57	22.61	30.27	26.44	27.40	26.44
Minimum Temperature (°C)	18.79	19.75	-52.11	-42.75	3.54	4.49
Change in Temperature (°C)	4.78	2.86	82.38	69.19	23.86	21.85
Final Temperature (°C)	20.70	19.75	3.54	4.49	27.40	26.44

IX. CAMERA/PHOTOMETER

J. K. Owens and K. S. Clifton

Two 16-mm photographic cameras, using Kodak Double X film, Type 7222, made stereoscopic observations of contaminant particles and background. Each was housed within a pressurized canister and operated automatically throughout the mission, making simultaneous exposures on a continuous basis every 150 s. The cameras were equipped with 18-mm f/0.9 lenses and subtended overlapping 20° fields of view. An integrating photometer was used to inhibit the exposure sequences during periods of excessive illumination and to terminate the exposures at preset light levels. During the exposures, a camera shutter operated in a chopping mode in order to isolate the movement of particles for velocity determinations. Calculations based upon the preflight film calibration indicate that particles as small as 25 microns can be detected under ideal observing conditions.

More than 1075 exposures were obtained by each camera during the time that the Orbiter payload bay doors were open. Of these, more than 500 frames had exposure times of between 1 and 80 s, with the length of the exposure dependent upon the background illumination recorded by the photometer. Preliminary analysis of the data indicates that as many as 45 exposures from each camera show potential contamination due to particulates. The low percentage of data frames indicating particulates is partly because contamination can only be detected during periods in which the Orbiter environment is sunlit and the background is dark enough not to mask the illuminated particle tracks. On the STS-2 mission this occurred only: (1) during sunlit passes in which the Orbiter -Z axis (see Figure II-1) was directed away from both the Earth and Sun and (2) twice each orbit when the spacecraft was between the terrestrial terminator and the umbra of the Earth's shadow and the Orbiter -Z axis was Earth-directed along the local vertical. The occurrences of these conditions were severely limited on STS-2 but will be considerably more frequent on STS-3 and STS-4. However, preliminary analysis indicates that a majority of data frames obtained during these conditions do not show contaminant particles.

The contamination recorded by the cameras sometimes took the form of "snowstorm" events, such as that shown in Figure IX-1, with sometimes better than 30 individual particle tracks visible in a single frame. Many of these events have been temporally correlated with water dumps, engine firings, and payload bay door activities. A number of frames show single tracks which must be discriminated from background (e.g., lights of cities) by further analysis.

The photometer section of the system is capable, in the configuration used on this flight, of measuring brightness levels, B, between $B/B_\odot = 2.972 \times 10^{-15}$, and $B/B_\odot = 5.573 \times 10^{-12}$, where $B_\odot$ is the solar brightness. The primary sources of error in the measurement are high voltage to the photomultiplier tube (PMT) and integration time, which were measured during the mission. It is estimated that the error

in PMT gain due to the uncertainty of the high voltage value is approximately 10 percent, and the integration time is known to $\pm$ 1 s. Therefore, the error in the background brightness measurement is $\Delta(B/B_{\odot}) = \pm 1.04 \times 10^{-14}$ for the longest exposure recorded, i.e., t = 80 s, or $\bar{B}/B_{\odot} = 6.9 \times 10^{-14}$. Figure IX-2 shows a 20-s exposure where $B/B_{\odot}$ is 10^{-13}.

Efforts are continuing in the correlation of these data with Orbiter events and include terminator and umbra crossings throughout the mission, sun angle, moon angle, and latitude and longitude toward which the -Z axis is pointed. Decay times for "snowstorm" events will be studied, and measurements of angular velocities and of particle distances from the camera will be made. Spatial and velocity distributions will be determined, as will the size of individual particles.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Figure IX-1. Typical particulate event. This event correlates temporally with a Reaction Control System (RCS) firing. The exposure time is 2 s; the chopping action of the camera shutter is evident from the broken particle tracks. This photograph was taken shortly after the photograph in Figure 2.

Figure IX-2. Nighttime observation of star field. This photograph was taken at approximately 2:30 MET, when the spacecraft was just entering the terminator from the night side of the orbit. The star field is in the constellation Gemini; the exposure is approximately 20 s. The sky background was approximately 10^{-13} $B_{\odot}$, and the limiting stellar magnitude appears to be $m_v = 8$.

X. MASS SPECTROMETER

E. R. Miller

The IECM quadrupole, 2-150 amu, Mass Spectrometer, developed by the Space Research Institute of the University of Michigan, is collimated by sintered zirconium getter pumps to 0.1 sr and is able to measure a collimated flux from approximately 10^8 to 10^{16} molecules/cm^2/s/0.1 sr. Each amu pulse count is integrated for 2 s, accomplishing a full sweep in 300 s, alternating with an equal number of steps on the water peak (amu 18). Thus, the full cycle requires 600 s, or 10 min. This cycle is repeated throughout the mission unless commanded to other modes [1]. Also, incorporated in the instrument is a ^{22}Ne, $H_2{}^{18}O$ gas release system which is designed to provide a measurement for evaluating differential scattering cross sections for collisions at Orbiter speeds (8 km/s). To accomplish this measurement, the gas is released as the Orbiter is maneuvered to scan the Mass Spectrometer/gas release pointing vector from 180° to 0° with respect to the Orbiter velocity vector.

The Mass Spectrometer unit #2 (Serial #002) was flown on STS-2. Ion source sensitivity calibration for unit #2 for selected masses is (in unit source density for 1 count/s):

Mass 4	He	$= 7.09 \times 10^3/cm^3$
Mass 18	H_2O	$= 1.19 \times 10^3/cm^3$
Mass 28	N_2	$= 1.08 \times 10^3/cm^3$
Mass 32	O_2	$= 1.08 \times 10^3/cm^3$
Mass 40	Ar	$= 7.14 \times 10^2/cm^3$
Mass 44	CO_2	$= 8.31 \times 10^2/cm^3$

Because of its anticipated prevalence as an offgassing constituent from the Orbiter and payloads, data analysis efforts for these quick-look results have been concentrated on results of water molecule measurements with respect to mission time and events.

After the instrument was turned on (3 hr, 25 min MET), stable operation was reached at approximately 5-6 hr MET (Fig. X-1). At 6 hr MET, the molecular count/2 s was approximately 2.7×10^4, requiring a source density of 1.6×10^7 counts/cm^3. The source density comprises both instrument background and return flux. The instrument background, measured prior to shipment of the Mass Spectrometer from the University of Michigan in March 1981, was determined to be 7×10^3 counts/s before seal-off for mass 18. Opening the instrument to vacuum at the Orbiter altitude of 223 km would begin to return background to the pre-seal value. The Orbiter was maneuvered to within 20° of wake (Fig. II-4) (160° from velocity vector) at 7 hr, 35 min MET, which provided an additional instrument background measurement since at this time return flux would be essentially zero. The count rate at 7:35 is approximately 1.7×10^4/2 s. Just prior to this wake position at 90° from the velocity vector the count rate was 2.1×10^4/2 s. This suggests that at this early time in the mission the background could be

from a minimum of 52% ($1.4 \times 10^4/2.7 \times 10^4$) to a maximum of 81% ($1.7 \times 10^4/2.1 \times 10^4$). These extremes would give estimated values of return flux density between $8.3 \times 10^{12}/cm^2/sr/s$ and $3 \times 10^{12}/cm^2/sr/s$ and column densities between $2.6 \times 10^{13}/cm^2$ and $9.5 \times 10^{12}/cm^2$. These values agree with estimates made by Scialdone [3] for the STS with payloads of certain known outgassing characteristics. These values further decrease by a factor of 3.5 after 20 hr MET and by a factor of 7.5 after 40 hr MET assuming the background ratio remained roughly constant. Requirement goals are less than $10^{12}/cm^2$ column densities after early outgassing.

In addition to the wake maneuver, several other mission-related events are evident in the count rate response for mass 18 (Figure X-1). At 8:55 MET the Orbiter performed a maneuver which caused the payload bay to come within approximately 5° of the velocity vector (Fig. II-4), at which time the count rate increased by approximately 10, as expected. At 11 hr MET the payload bay came within approximately 40° of the velocity vector (Fig. II-5), and a slight increase in count rate is noted. At 11:49 MET a supply water dump was started and ended at 12:25, giving significant count rate increases. At 21:39 to 23:19 MET, the water evaporator was operated. It is unclear at this time what the peaks at about 27:30 to 32:00 are related to, although the Remote Manipulator System was being tested from approximately 23 to 28 hr MET. The primary Reaction Control System engines may have been fired at 27:39 MET.

When the IECM was turned off, data were lost from approximately 33:35 to 36:42 MET. At approximately 47 and 48 hr MET the payload bay was pointed alternately toward and away from the velocity vector and at 49 hr again into the velocity vector during which time the instrument was turned off in preparation for deorbit.

It is emphasized that detailed analysis of mass 18 has just begun and that no analyses of the other mass peaks have been accomplished. However, a list of all the apparently significant mass peaks is given for completeness. (Some of these peaks may not be significant when instrument background is taken into account.) The significant early mission count rates occur at amu 2, 4, 12, 13, 14, 15, 16, 17, 18, 25, 26, 27, 28, 29, 30, 32, 39, 40, 41, 42, 43, and 44 for lighter masses. Only a few heavier masses (50-150 amu) with significant count rates are present: amu 55, 56, 57, 60, 64, and 78. The count rates for these heavier masses are generally lower by a factor of 100 or more when compared to the lighter masses.

The Ne, H_2O gas release was performed at 33:05 MET and terminated at IECM power down at 34:00 MET. The Shuttle attitude remained at 90° with respect to the velocity vector and did not perform the required scan maneuver. Results of this limited experiment are still being analyzed.

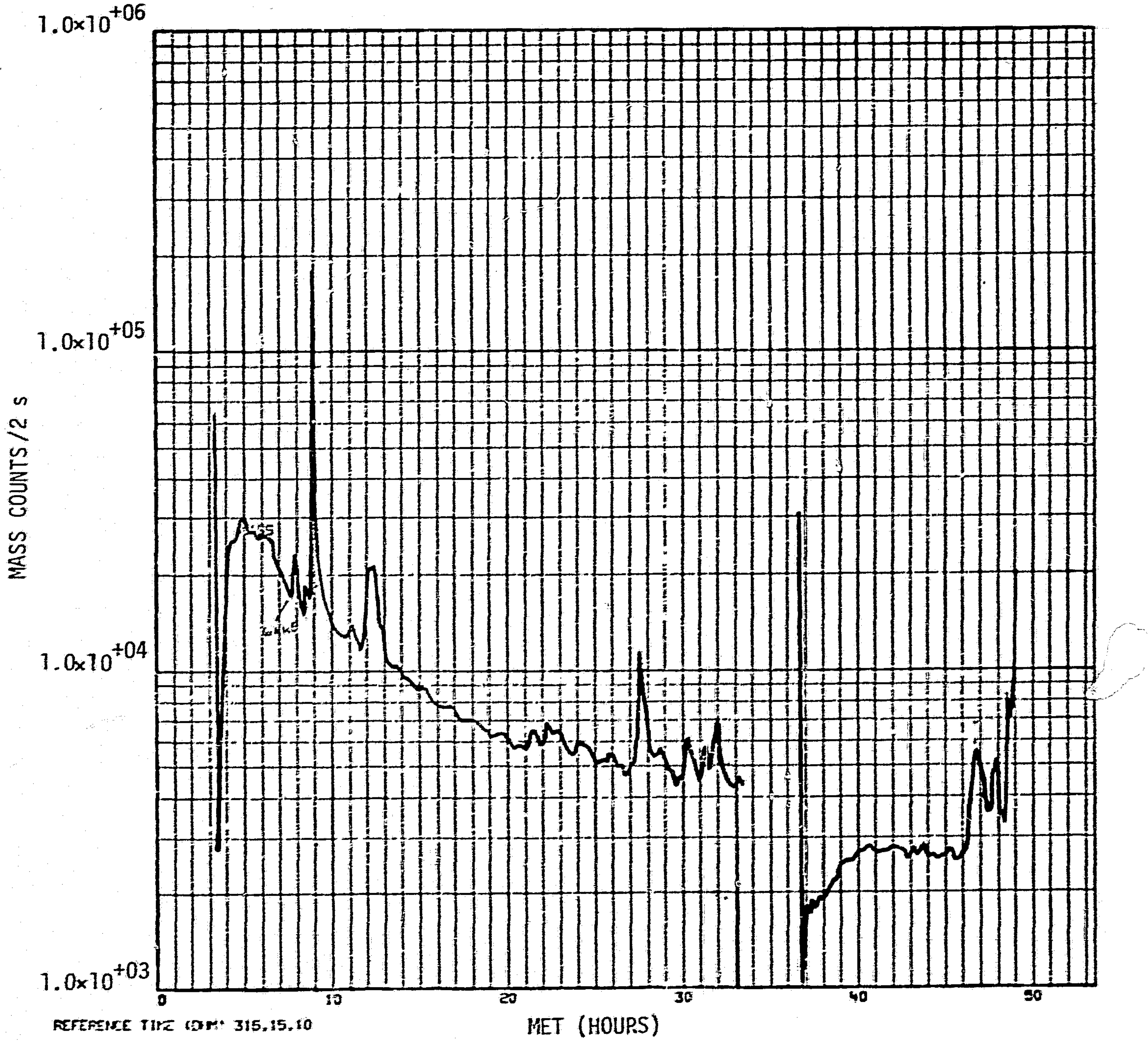


Figure X-1. IECM Mass Spectrometer, flight STS-2: mass counts versus time at amu 18.

XI. CONCLUSIONS

E. R. Miller

The performance of the IECM on the STS-2 was nominal throughout the mission, responding properly to all commands and sequencing the instruments in proper order and mode. Although this first IECM flight provided initial data for all phases of the mission, the on-orbit phase was limited to essentially "early mission" time by the shortened flight.

The overall results are encouraging at this early stage of development of the STS. A maximum of 16 percent relative humidity was measured during descent/postlanding. The ascent and descent air sampling do not show detectable HCl or nitrogen compounds, respectively. Considerable dustfall was indicated from the preflight OPF exposure, and excessive particle detection was seen on ascent and descent for particles < 5 micrometers diameter. There was no direct indication, other than particulates, of contaminants on optical samples for the entire mission, although there were small transmittance changes measured during the mission. The quartz crystal microbalances indicated low rates (except for brief periods) of mass accumulation, and the accumulation rate was generally decreasing during the orbital portion of the mission. The return flux and column density estimates for water appear to be within the predicted value ranges.

It is emphasized that these early analyses do not take into account all the Orbiter-related contamination events, such as thruster firings, exact times and duty cycles of water dumps and flash evaporators, and Orbiter temperatures. In addition, the Orbiter maneuvers were calculated and may not be precise. Also, the contributions to the overall environment from the DFI and OSTA-1 payloads are unknown.

These results should be used only as a preliminary guide and not as a final report on the STS induced environment. As originally planned, additional measurements are required under varied, more extreme, thermal conditions and, of course, longer flight times to better quantify data in several areas, including: offgassing decay rates, direct Orbiter/payload bay effluent mapping, and the on-orbit particulate environment. Multiple flights are also needed to obtain flight-to-flight variations related to different payloads and thermal/vacuum exposure clean-up of the Orbiter, and, finally, effects of cleaner processing facilities and payload bay cleaning efforts at KSC.

XII. FUTURE PLANS

E. R. Miller

The IECM was refurbished after the STS-2 flight and mounted in the Columbia on January 7, 1982, in preparation for STS-3. The 7-day flight of STS-3 will provide contamination data during cold and hot cargo bay extremes. The IECM is also scheduled to participate in a test of the Remote Manipulator System (RMS) which moves the IECM about the vehicle during a cold case. The contamination and engine plume pressure surveys originally scheduled for this mission are no longer planned, although the former is still considered a possibility to be performed. The gas release/maneuver is planned for STS-3. It is planned to perform the contamination mapping and engine plume surveys during the STS-4 mission.

After STS-4, the IECM will be integrated into the Spacelab 1 payload and will later make its final scheduled flight on Spacelab 2, measuring experiment-laden STS environments for a long Spacelab module-plus-pallet and a pallet-only case, respectively.

REFERENCES

1. Miller, Edgar R., and Decher, Rudolf: An Induced Environment Contamination Monitor for the Space Shuttle. NASA TM-78193, August 1978.

2. Linton, R. C.; Miller, E. R.; and Susko, M.: Passive Optical Sample Assembly (POSA): Final Report. NASA TM-82446, August 1981.

3. Scialdone, J. J.: Assessment of Shuttle Payloads Gaseous Environment Contamination and Its Control. Proceedings of ESA Symposium on Spacecraft Materials, October 2-5, 1979, ESA-SP-149, December 1979.

APPROVAL

STS-2 Induced Environment Contamination Monitor (IECM) — Quick-Look Report

Edited by E. R. Miller

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

Rudolf Decher

RUDOLF DECHER
Chief, Space Physics Division

for William C. Snoddy

J. E. KINGSBURY
Acting Director, Space Sciences Laboratory

☆U.S. GOVERNMENT PRINTING OFFICE 1982—546-071/134 REGION NO. 4

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TM- 82457		

4. TITLE AND SUBTITLE
STS-2 Induced Environment Contamination Monitor (IECM) — Quick-Look Report

5. REPORT DATE
January 1982

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Edited by E. R. Miller

8. PERFORMING ORGANIZATION REPORT #

9. PERFORMING ORGANIZATION NAME AND ADDRESS
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

10. WORK UNIT NO.

11. CONTRACT OR GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
National Aeronautics and Space Administration
Washington, D.C. 20546

13. TYPE OF REPORT & PERIOD COVERED
Technical Memorandum

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared by Space Sciences Laboratory, Science and Engineering Directorate, NASA/MSFC

16. ABSTRACT

The STS-2/Induced Environment Contamination Monitor (IECM) mission is described. The IECM system performance is discussed, and IECM mission time events are briefly described. Quick-look analyses are presented for each of the 10 instruments comprising the IECM on the flight of STS-2. Finally, a short summary is presented and plans are discussed for future IECM flights providing more extreme thermal environments, longer on-orbit durations (important for determining offgassing decay rates), and opportunities for direct mapping of Orbiter effluents using the Remote Manipulator System.

17. KEY WORDS

18. DISTRIBUTION STATEMENT
E. R. Miller
Unclassified — Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	78	NTIS

MSFC - Form 3292 (Rev. December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151